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A methodology for assessment of opportunities for computer-integrated manufacturing (CIM) and for development of an integrated business strategy for manufacturing-oriented companies /

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A METHODOLOGY FOR ASSESSMENT OF OPPORTUNITIES FOR COMPUTER-INTEGRATED MANUFACTURING (CIM) AND FOR DEVELOPMENT OF AN INTEGRATED BUSINESS STRATEGY FOR MANUFACTURING-ORIENTED COMPANIES

by

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C O N T E N T S

ABSTRACT

This thesis proposes a formal approach to planning for the implementation of computer-integrated manufacturing (CIM) technologies. It is intended to help maximize the strategic value of CIM implementation by emphasis on enterprise-wide benefits. The principal problem identified by the investigator's research was a failure of business enterprises to prepare comprehensive plans for the implementation of CIM technologies, often leading to the installation of isolated "islands of automation."

The proposed methodology enables manufacturing enterprises to assess opportunities for the utilization of CIM technologies and to develop an integrated implementation strategy by means of six stages:

1. **Program initiation** focuses on the education of senior management in integration concepts and CIM technologies with the objective of obtaining strong and consistent support for the CIM program.

2. **Program organization** addresses (a) the estbalishment of an organizational structure consisting of a CIM steering committee and a CIM task force, (b) formulation of preliminary strategic goals for the enterprise, (c) planning of a company-wide education and training program, and (d) establishment of project management guidelines.

3. The **"As Is" analysis** enables all levels of management to comprehend the existing infrastructure of the enterprise by capturing the characteristics of the business and utilizing modeling techniques to permit company personnel to conceptionalize functional operations.

4. The **needs analysis** establishes a hierarchy of functional requirements in relation to critical success factors (CSFs) established for the business and permits the systematic analysis of the applicability of CIM technologies to addressing these requirements.

5. **Conceptual design** activities focus on formulating a "To Be" scenario for the CIM implementation program and asssessing the potential impact of each technology on the overall operations of the business for the purpose of formulating a generalized set of specifications for CIM

implementation.

6. The **master plan** developed in the final stage serves to guide the CIM task force in final evaluation of CIM technology applications, development of a time-phased action plan for implementation, and establishment of monitoring procedures.

The results of applying the proposed methodology in three manufacturing enterprises generally support the hypothesized benefits. The fact that only portions of the methodology were utilized in these case examples demonstrates the flexibility of the proposed methodology.

I: I N T R O D U C T I O N

The computer and its associated software offer manufacturing-oriented companies a powerful tool for achieving the necessary flexibility in production-related activities (Snodgrass, 1984). More important, however, are the computer's capabilities for logically integrating all business activities, and the resources utilized in their performance, through the sharing of information. This implies that computer-integrated manufacturing (CIM) technology will be a necessity for any manufacturing-oriented firm that wishes to compete effectively in modern world markets.

DEFINING COMPUTER-INTEGRATED MANUFACTURING (CIM)

The term "computer-integrated manufacturing" (CIM) can have a variety of meanings, depending on who is describing it and what application is being addressed. The Computer and Automated Systems Association (CASA) division of the Society of Manufacturing Engineers (SME) provides a useful general description of CIM:

> CIM is a new enterprise-wide process for industrial automation. It appears as a special program under which industrial automation projects are planned, executed, and integrated.
>
> CIM introduces a third perspective on industrial automation, as a complement to the user and technical perspectives. It is this enterprise perspective which provides the common ground for integration and sharing, and which ensures quality, consistency and flexibility in the total automated structure of the enterprise.

Although useful, this description creates some problems in that it appears to rank industrial automation as the primary objective of CIM. It is true that industrial automation is usually one component of CIM, but the main concern of CIM lies in the second letter of the acronym: "I" for integration. The objective of CIM is to integrate all functions throughout a manufacturing enterprise (Gunn, 1986).

It is common for individuals and industry publications to intepret CIM as referring only to design and production functions, ignoring its wider applications. This error is partly inherent in the name itself, which logically should be replaced by a new acronym, "CIB," standing for "computer-integrated business." However, the propagation of yet another acronym in a field already crowded with jargon might serve only to further confuse the issue.

Business firms involved with automation and computer technologies already employ a multitude of acronyms including CIM, MRP, CAD, CAM, JIT, FMS, and a host of others. The confusion is compounded because these terms are not consistently understood or employed. Clarifying definitions and applications is one of the major educational tasks in employee education confronting management in any enterprise contemplating the implementation of CIM technologies.

The purpose of this thesis is to present a methodology for planning an effective CIM program. One of its underlying assumptions is that the definition of CIM should be broadened to include the overall operations of a manufacturing-oriented business. The term CIM is used throughout to refer to the integration of all systems, personnel, and resources to improve the efficiency and competitive efficacy of the entire enterprise.

ADVANTAGES OF COMPUTER-INTEGRATED MANUFACTURING

The implementation of computer-integrated manufacturing can have far-reaching effects on modern business operations. Manufacturing operations of all types are finding that their contemporary production requirements include improved flexibility, shorter runs, greater customization of products, faster responses to changes in market demand, greater control and accuracy of processes, and quicker throughput (Goldhar & Jelinek, 1983).

These requirements can be met only if managers carefully and intelligently apply new CIM technologies. The successful application of CIM technologies will requires that management and production personnel "unlearn" a host of assumptions based on scale--that is, production of large quantities of undifferentiated products in order to attain efficiency in manufacturing and customer service (Goldhar & Jelinek, 1983)

In addition, management will have to realize that focusing on portions of the business operations rather than considering the business as a whole has detrimental strategic consequences: partial rather than overall solutions to business problems. Today's successful managers will be those who take strategic considerations into account. Such considerations include:

- o Customization of products to meet the needs of individual customers and finely tuned market segments.
- o Increased variety and proliferation of

families of product designs.

- Tying production runs closely to demand and responding rapidly to orders for new products as well as replacement parts. This requires enhancement of production capacity, reduction of inventories, and reduction of warehousing.
- Advertising and promotion emphasizing production process capabilities--quality, reliability, and responsiveness to customer needs instead of the design characteristics of the product.
- Accelerated incorporation of new CIM and state-of-the-art technology. (Goldhar & Jelinek, 1983)

Computer-integrated manufacturing can be instrumental in improving a company's competitiveness in today's market. However, considering all tactical and strategic aspects of a company's particular situation is crucial to developing an effective CIM-based operation. The benefits of CIM are real, but they are attainable only with proper planning and preparation.

II: DEFINITION OF THE PROBLEM

Many manufacturing firms are becoming aware that being competitive in a global market requires investment in the latest technology combined with improvement of manufacturing operations. Manufacturing systems often represent the major portion of an industrial company's human and financial assets, yet managers have been slow to acknowledge the central importance of these systems to the overall performance of their organizations. In order to make better-informed business decisions, managers require condensed, integrated information about all aspects of their enterprises, including marketing as well as manufacturing. (Goldhar & Jelinek, 1983)

To achieve the optimum combination of new technology and operational integration, U.S. firms are increasingly turning to CIM (Neggi, 1984). Unfortunately, they often find that their overseas competitors have already done so. For example, some

Japanese companies have advanced their operations to such a degree that they are in a much better position to offer superior products than their U.S. competitors are. A common scenario is the following:

1. Company executives realize that they are behind in an area that has proved to be critical to their firm's competitive position. They decide that prompt action is imperative.

2. Often, a member of lower-level management, who perhaps is not critical to day-to-day operations, is assigned to investigate CIM with the least possible disruption of current operations.

3. Having delegated the task of investigating CIM, high-level executives frequently make no effort to learn the concepts underlying CIM technology and provide only minimal support to the team assigned to the task.

4. The emphasis may be placed on finding a "quick fix" while the overall operation continues in the patterns of past years.

5. Complacency about past business success sometimes combines with resistance to change to foster the idea that assigning someone to investigate CIM is tantamount to doing something about the company's

problems.

The consequences of this scenario are obvious. No overall plan will be developed. The entire project may be abandoned or, at best, islands of automation or nonintegrated manufacturing systems will be installed. Lacking the appropriate resources or support, but under pressure to "do something," the manager in charge will install technologies that appear to be solutions to whatever isolated problems are apparent.

The scenario just described is not universal, but it is alarmingly common. The problem lies in the approach employed by most companies that seek to understand and implement CIM technologies.

CIM technologies are new to most U.S. firms. New technology and terminology is continually being generated by the firms that manufacture high-technology systems and equipment and by the industry press. It appears as though the only U.S. companies capable of understanding and keeping abreast of CIM technologies are firms like IBM, Westinghouse, General Electric, and Allen Bradley, who develop the technologies, and the relatively few firms that can afford to hire large staffs devoted exclusively to researching and developing their companies' assimilation of new computer-based technology--firms like John Deere, General Motors, Ford, and Boeing.

However, the mere possession of vast assets and large, dedicated staffs is not the key to effective use of CIM technologies. The key is planning, which in turn leads to high-level management support, education and training of personnel, and relevant organizational change. Planning for CIM is critical; without it, manufacturing-oriented firms will not achieve the modernization and technological expertise they need to survive. The consequences of lack of planning are potentially devastating, both for individual firms and the U.S. manufacturing community as a whole. (Productivity International, Inc., 1981)

Despite its critical importance, planning for CIM has been underemphasized, or worse, overlooked entirely. The omission or underutilization of planning can be attributed to various factors including lack of foresight, lack of experience, and impatience to "do something" about real or apparent deficiencies. The result has been islands of automation that may not be employed to maximum benefit because they were installed without consideration for the overall operation of the business or its future needs.

When computer-based technologies are installed in response to superficial needs, CIM concepts cannot be effectively applied to overall corporate strategy. This lack of integration prevents corporations from obtaining the maximum benefits from their technological investment.

THE IMPORTANCE OF CIM PLANNING

The consequences of underutilizing or ignoring comprehensive planning for CIM include:

- o Approaching CIM without direction.
- o Failure to develop workable subcomponent tasks whereby completion in sequence will lead to a comprehensive approach to CIM.
- o Random proliferation of systems and automation which may not even address the real needs of the business but may serve instead to automate operations that are already in place but are not really serving the intended purposes.

These and other problems will develop if a company fails to engage in a comprehensive and completely committed CIM planning effort. To avoid such problems and to devise a successful CIM approach to modernize business operations, management must proceed from an overall business perspective instead of focusing on discrete operations.

There is at present no single, systematic, and accepted CIM planning methodology to assist managers in addressing the intangible as well as the tangible aspects of business strategy and operations (Elavia, 1985). Such methods as are currently available are tedious and difficult to follow, and they require extensive resources and the services of specialists. Small and medium-sized companies that could benefit from CIM often do not have the resources to accomplish the planning task utilizing available methodologies. Moreover, these methodologies do not provide an overall picture of the company's needs and therefore do not foster the development of a good master plan for CIM.

The purpose of this investigation was the research and development of a comprehensive methodology for CIM planning that is more readily accomplished by personnel with a broad range of skills. The methodology presented will enable manufacturing-oriented industries to assess opportunities for utilization of CIM and to develop an integrated strategy for successful design and implementation of CIM technologies.

III: METHODOLOGY

There are many publications describing the components or elements of CIM. New components are continually being added to an already bewildering array (see chart below).

Most companies begin their implementation of CIM by selecting one or more components that appear to address some obvious but often superficial operational problem.

A Sampling of Available CIM Technologies
(Waterman, 1986)

- Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM)
- Computer-Aided Engineering (CAE)
- Group Technology
- Automated Process Planning/Engineering
- NC (Numerical Control), CNC (Computer Numerical Control), DNC (Direct Numerical Control)
- Communications/Networking
- Simulation
- Database Management Systems
- Automation Engineering
- Management Information Systems (MIS)
- Manufacturing Resource Planning (MRP II)
- Just-in-Time (JIT)
- Artificial Intelligence (AI)

Although these components are the fundamental structure of CIM, randomly selecting and combining them is analagous to a physician's prescribing medications without first diagnosing the disease.

The "supermarket approach" to CIM--simply selecting the technologies that appear intriguing--is both inappropriate and ineffective. CIM planning must begin with a concentrated evaluation of the needs of the industry and the individual firm, followed by an assessment of which tools might be utilized to improve the overall operations of the firm. Such an evaluation can be facilitated by a universally applicable methodology for assessing CIM opportunities and developing an integrated business strategy for CIM planning.

A METHODOLOGY FOR CIM PLANNING

The CIM planning methodology developed in this thesis consists of six major stages: (1) program initiation, (2) program organization, (3) "as is" analysis, (4) needs analysis, (5) conceptual design, and (6) development of a master plan (Punwani, 1985). Following these stages will provide a solid foundation on which companies that wish to improve their competitiveness through investment in CIM technologies can build an effective CIM program. The author has developed these stages in the course of involvement with CIM programs in various industries and through analysis of the literature describing successful implementation of CIM (Punwani, 1985).

It is crucial that these stages be completed systematically and sequentially. The information developed at each stage is utilized in the stages that follow. Managers may be tempted to omit stages in the belief that they already possess an adequate understanding in those areas. The "as is" analysis is often omitted or given superficial attention for this reason. However, investigation of current operations as proposed in this thesis proceeds from a perspective different from that which prevails in most companies. By not thoroughly participating in all the stages to be described, a company can seriously jeopardize its CIM program.

A brief overview of the components of the six stages is presented here. Each stage is then discussed in detail in the relevant section of this chapter.

Program Initiation

The first stage, program initiation, is just that--the approach for starting off the CIM planning cycle and the overall CIM program. This stage addresses top management and concentrates on generating interest in the CIM program and assuring management support. It includes (a) presentation of or introduction to the benefits of CIM, (b) education of top management regarding CIM technologies, (c) presenting integration concepts, (d) reinforcing the importance of CIM planning, (e) defining the role of top management, (f) education and training of personnel, and (g) investment justification.

Project Organization

This stage begins with the establishment of a cross-disciplinary project team that will be responsible for project management at the departmental level. Project management and organizational considerations will be addressed by this stage of the CIM planning program, which includes (a) forming a steering committee composed of representatives of top-level management, (b) organizing a project team, (c) setting initial strategic goals for the organization, (d) informing the employees of the CIM program, (e) developing plans for a company-wide education program, and (f) developing formal project management procedures.

"As Is" Analysis

This is the stage where actual investigation into company operations begins. The theory underlying "As Is" analysis is that those responsible for planning future business strategies require a thorough, detailed understanding of what is currently taking place in the company. Once all the information is compiled, this investigation into current operations will provide a detailed over view of the business. Components of the "As Is" analysis include (a) developing facility and equipment profiles, (b) performing a product flow analysis, (c) defining a business function hierarchy, (d) documenting information flow, (e) developing an operational cost model of the business, and (f) documenting the employee knowledge base.

Needs Analysis

This stage is designed to identify business functions that could be improved though the application of CIM technologies or by simple procedural improvements. Business functions are analyzed in light of the business strategies determined to be appropriate by top management. The needs analysis includes (a) performing a market analysis, (b) identifying business function areas for improvement, (c) defining functional improvement requirements, (d) assessing application of different component technologies, and (e) determining improvement potential for each business function.

<u>Conceptual Design</u>

This fifth stage consists of determining the "best fit" between the oportunities for improvement and the potential applications of CIM technology developed in the previous stage. First, each identified functional area of the company, the CIM component technology, and the overall effect of that particular technology on the company's operations, must be analyzed in detail. This analysis provides the basis for a conceptual design of the company operations, including the proposed CIM technologies. Thus, the conceptual design stage includes (a) determining the "best fit" between business needs and recommendations for functional improvement, (b) performing a risk analysis on the recommendations, (c) performing a cost/benefit analysis for each functional area, (d) estimating benefits to the overall operation of the business, and (e) presenting a conceptual design to the steering committee.

Development of a Master Plan

At this final stage, all the work completed in the preceding five stages is used to develop a final CIM plan. The conceptual design is employed in reassessing the application of CIM technologies in achieving the overall business strategy put forth by top management. Each application of CIM technology is assigned a priority, and a time-phased implementation plan is developed. Thus, the master planning stage comprises (a) formulation of an integration strategy that will address business objectives, (b) evaluation of CIM modules, (c) development of a time-phased implementation plan, (d) development of procedural mechanisms for monitoring actual versus estimated benefits, and (e) presentation of the completed master plan to the company executives and others with a major stake in the company.

The master plan stage completes the CIM planning cycle, which would logically be followed by an implementation cycle. This thesis confines itself to a comprehensive investigation of planning, the most critical, and the most frequently overlooked phase of any CIM project.

The foregoing outline of the proposed CIM planning methodology has been presented to give the reader a basic understanding of the stages involved. In order to undertake a program of CIM planning, a company will require a detailed approach document to assist it in addressing all aspects of this critical cycle. The following sections provide a detailed description of the stages necessary to complete the planning task. project.

PROGRAM INITIATION

Just as the planning phase of the entire CIM program has primary importance because it sets the program's foundation, the program initiation stage of the CIM planning cycle sets the tone with respect to top-management involvement.

No CIM program should be initiated until and unless top management has committed itself to in-depth involvement and full support, for no CIM program can succeed unless upper-level management give it their total support from the outset (Productivity International, 1981). A key factor in achieving top-management support is to promote the strategic importance of business operations. Recognition of this importance should orient top management toward including CIM in the company business plan.

Promoting Management Interest

A company's initial interest in CIM technologies may be generated in various ways and at various levels. An upper-level manager may be exposed to CIM concepts at a business conference. An individual in marketing may have learned that competing firms are investigating CIM applications. A functional manager may believe that computer integration is applicable to his or her area of operations. Regardless of the source of initial interest, a company should have a logical plan for investigation of CIM applications.

Once interest in CIM has been generated, the appropriate people in the organization must be motivated to take an active role in further investigations. If the initial interest originated with the CEO, promoting interest among upper management will be more easily accomplished than if a manager at a lower level is promoting specific applications. The latter case, the proponent of CIM must enlist the support of a key member of upper management. In other words, a senior manager who will give consistent support to the CIM program must be identified and recruited to give the program the necessary leverage to get started.

The CIM champion is usually someone like the vice president of manufacturing or the director of the information systems department--someone who understands the implications of CIM. The important thing to remember is that interest in CIM concepts must be fostered in upper management, lest the company mistakenly overlook vital strategic considerations.

Often it is lower-level managers who generate an interest in CIM applications because they are closest to the technological aspects of the business. Senior managers, on the other hand, tend to be oriented toward high-level strategic aspects of the business. They are unlikely to have come from a technical background; studies have shown that the senior management personnel of most U.S. manufacturing-oriented companies come from legal, financial, or marketing backgrounds. Consequently, they have a vague understanding of manufacturing as it was five or ten years ago, let alone what it may be five to ten years hence. (Gunn, 1986) Therefore, it is usually a challenge to promote

CIM concepts to upper management, and this is why a CIM champion, usually from manufacturing, must be fostered.

The program initiation phase of the CIM planning cycle contains two steps that are crucial to promoting management involvement: (1) presenting the benefits of CIM and (2) educating senior management in regard to CIM, including its strategic aspects.

Presenting the Benefits of CIM

Computer-integrated manufacturing is like any other program in that its concepts must be "sold" to top management before any serious attention will be paid to the program. Thus, the first step in initiating a program is to present upper management with a comprehensive review of its potential benefits. Top management must be exposed to the ideology of CIM and the ways in which it will benefit overall company strategy as well as specific functional operations.

The most important aspect of this step is a carefully prepared presentation to upper management. This presentation should be carefully tailored to the upper-management perspective. It should not be a technical review of CIM concepts; rather, it should be a high-level introduction to computer-integrated manufacturing.

Often, management is unfamiliar with or even hostile to computer technologies. In such a case, it is better to use alternative terminology to mitigate any initial negativity. For example, the program can be introduced as a company-wide integration program. Integration is a broader conceptual term and will not intimidate those individuals who are uncomfortable with computers.

Another important aspect of the presentation is to highlight those benefits that address strategic issues. Senior managers will logically ask why they should appropriate valuable resources to a company-wide CIM program. One of the best-known sources of documented information of the benefits of CIM is a survey conducted and published by the National Resource Council: Computer Integration of Engineering Design and Production: A National Opportunity (Washington, D.C.: National Academy Press, 1984). Some of the benefits presented are shown on the chart below.

By presenting management with these documented benefits achieved by companies that have implemented CIM, the task of generating management interest should be greatly simplified. Upper management should begin

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Partial List of CIM Benefits Found in NRC Survey

- o Reduction in engineering design costs . . 15 - 30%
- o Reduction in overall lead time . . . . . 30 - 60%
- o Increased product quality . . . . 2 - 5 times
- o Increased capability of engineers as measured by extent and depth of analysis . . . . 2 - 35 times
- o Increased productivity of maufacturing operations . . . . 40 - 70%
- o Increased utilization of capital equipment . . . . 2 - 3 times
- o Reduction of work in process . . . . . . 30 - 60%
- o Reduction of personnel costs . . . . . . 5 - 20%

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considering how some of these benefits could improve their company's competitive position. Management from virtually any company should be able to identify a few of the listed benefits as having the potential to vastly improve their position in the marketplace.

During this initial presentation, those attending should be encouraged to brainstorm strategic advantages that these CIM benefits might provide. From the very beginning, management should be considering the utilization of CIM technologies to achieve strategic goals for their particular business.

Although this initial presentation has educational properties in its own right, its primary purpose is to stimulate top-management interest in applying CIM technologies to strategic goals. The next step is the more specific education of management regarding CIM concepts.

Educating Top Management

Although the benefits of CIM have been presented, it is unlikely that management has fully assimilated the strategic importance of modernization. A vital part of obtaining top-management support for CIM is to acquaint senior management directly with current technology through visits to the design and manufacturing areas of their own firms and those of other, progressive companies in their industry (Gunn, 1986). They should also be encouraged to visit modern CIM showcases. Such investigations will enable them to see for themselves that modernization is taking place in their industry, and that unless they participate, their competitors will have an advantage over them in product quality, product cost, and customer service.

Once aware of the risks they are taking by operating passively as they have in the past, senior managers will be more receptive to commiting resources to a CIM program of their own. At this point, they need to learn how to go about obtaining the benefits that have been presented. They should be advised that the most important aspect of a CIM program is integration.

Introducing Integration As a Concept

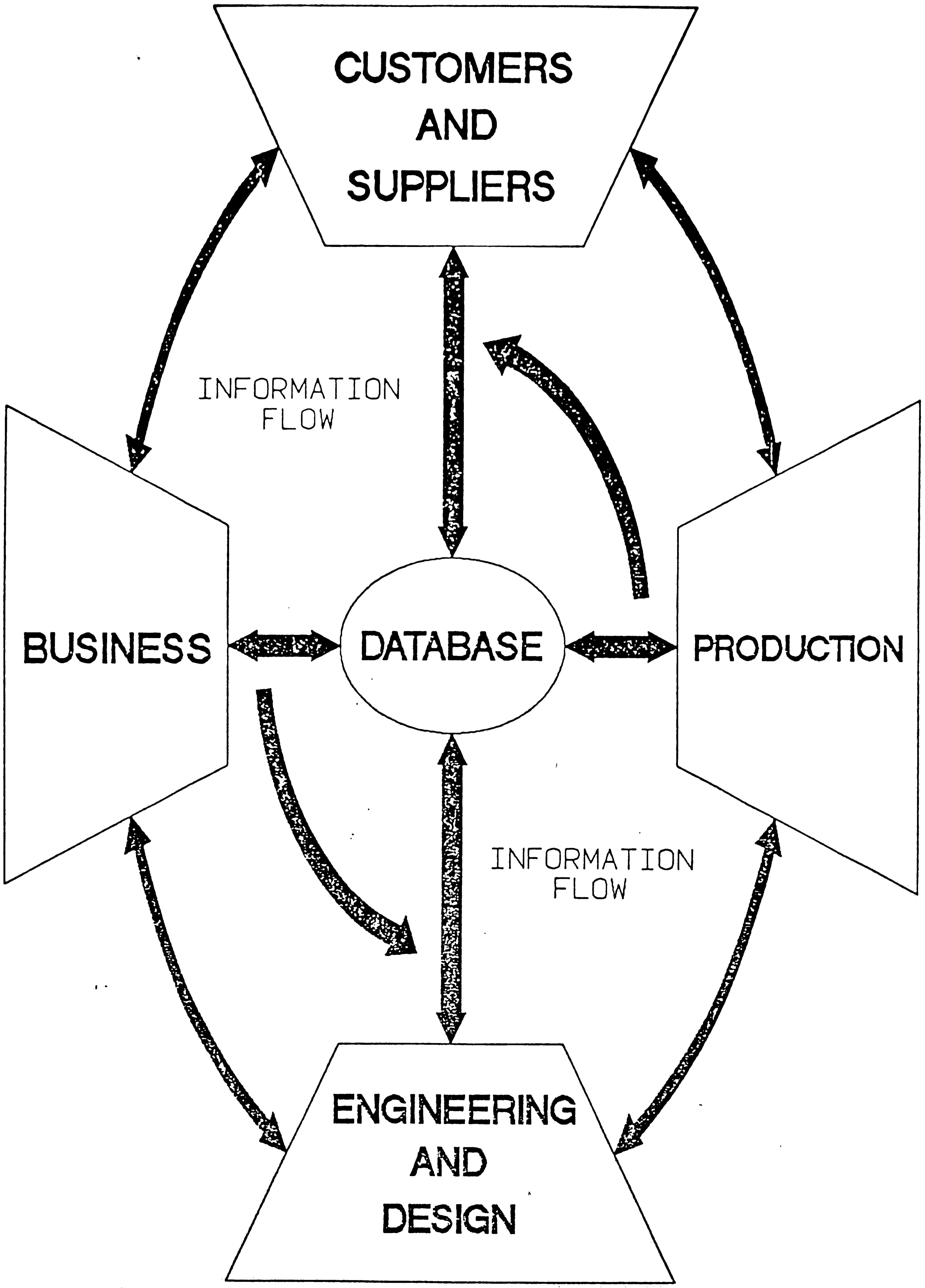
The executives of a company contemplating a CIM program must understand that integration is a management process, not a set of technologies, a system, a product, or a single project (Productivity International, 1981). More specifically, many managers have the impression that integration consists of interfacing within islands of functional automation or simply setting up communications between a few system. Applications of this kind are merely subset projects within an overall CIM or integration program.

Integration is a fundamental objective which can be achieved by assimilating new technology that will assist in linking all key areas of a business. Through integration, a company can maximize its effectiveness as an organization to compete in the marketplace. To achieve integration, a company must plan, build, and manage an integration program. This program will require consistent senior-management input and monitoring to ensure that its strategic objectives are being addressed. Whether the program is labeled a "CIM program" or an "integration program" makes no real difference to the approach. (Savage, 1985)

Once senior management have been convinced of the importance of integration, they must be advised on how best to approach it. The best place to start is with basics, and the most basic concept in integration is information. An integration process is designed to handle, manipulate, transfer, combine, and manage the information that drives a company's operations.

Senior management will be required to make a commitment to managing information as a valuable company resource. To understand what is involved in integrating their company, they must first understand that integration is based on sharing information among all functions within the company. This involves the collection of data from all areas of the company's operations, accumulating data in a central database management system, and then distributing the compiled information to the appropriate destinations (Figure 1). Therefore, information is the product of various value-added operations. It is first collected in the form of data. Then, through the application of other company resources, these data are developed into useful

Figure 1 Integration as a Sharing of Information
(The Yankee Group, 1987)



information which can be compiled and utilized as a valuable resource.

In order to collect data and compile information in a timely and cost-effective way, a means of transferring data and information automatically will have to be provided. The most efficient means of collecting, compiling, and transferring data and information is with the assistance of computers and new computer-related technologies such as networking, database managers, and decision support systems. Senior management will have to commmit the resources necessary to improving the efficiency of information processing in their company.

Except for the most common computer-assisted applications such as labor reporting and accounting, most manufacturing-oriented firms currently collect and transfer information in the form of paper systems. Over the years, as senior management have needed additional information about their operations, additional employees have been hired to process that information. The fact that overhead costs have nearly doubled since 1955, to the point where they equal manufacturing costs, is evidence of this fact (Young & Meyer, 1984).

A major contributor to overhead costs are nonproductive employees--that is, those who do not directly add value to a product. In 1955, 16.5 percent of the manufacturing workforce was nonproductive; the present level is 30 percent. Of these 30 percent, 50 percent--that is, 15 percent of the total workforce--are "white collar" workers. These people are engaged in creating, analyzing, transmitting, and managing the information needed to support production. When examining the benefits of CIM, many managers concentrate on reducing the productive workforce only, ignoring the improvements that CIM can effect in white-collar productivity and in their own effectiveness as decision makers. (Young, 1984)

Human resources are much too expensive and valuable to be dedicated to collecting, manipulating, and transmitting information. Instead, human resources should be utilized in analyzing the information and drawing conclusions about how the company can improve its operations. Conversely, computers and the new computer technologies were designed specifically to collect, manipulate, and transfer data and information. Utilization of these technologies will greatly improve the effectiveness of business operations, thereby providing the company with a competitive advantage. Senior management must be prepared to invest a substantial amount of resources in information management and integration.

Once upper management comprehend the importance of integration and its dependence on the timeliness and availability of information, it is time to go on to learning exactly what is involved in undertaking a successful integration (CIM) program. This includes the importance of CIM planning, the role of top management, the necessity for education and training of personnel, and justification of the investment.

Presenting the Importance of CIM Planning

Upper management must be made aware of the importance of planning, including the investment of time and resources "up front" to prevent the occurrence of overwhelming problems later in the program. The CIM planning process involves high-level strategy and tactics, but once the initial overall plan is completed, flexibility remains necessary. CIM must be continually planned and replanned in response to the dynamic changes that occur in all businesses and in the marketplace as a whole. The importance of forethought in avoiding problems must be continually emphasized.

At this time, the remaining stages of the CIM planning methodology should be presented and described: program organization, "As Is" analysis, needs analysis, conceptual design, and master planning. Brief descriptions of each stage similar to those presented in the section on CIM planning can be utilized. This presentation will demonstrate the magnitude of the CIM planning program and dispense with the notion that it is a small task that can be readily delegated to a few individuals and then ignored.

Explaining the Role of Top Management

Senior executives need to understand that setting the tone for a total company effort is their responsibility. Without constant support at the top, lower-level managers will permit interdepartmental communication problems and politics to stifle the integration (CIM) program. Conversely, if senior executives demonstrate that they are serious about the program, everyone at lower levels will take it seriously, too. (Savage, 1985)

A major role of senior management will be participation in the program organization stage described in the subsequent section. This stage includes organization of a steering committee composed of senior management to guide the direction of the integration (CIM) program.

A more immediate role of senior management will be the identification of the company's strategic goals. As part of the initial education for senior executives, proponents of the program should stress that it is senior management that will set the parameters for the company's integration program. It is they who will set goals for the company in such areas as quality performance, price competitiveness, customer service, and product innovation. Once they have set the strategic goals, the integration program can be directed toward these objectives.

The Importance of Education and Training Of Personnel

Familiarizing top management with the need for education and training of personnel at all levels has primary importance. Often, management undertakes a CIM program without fully understanding what is involved in educating and training personnel to work in an integrated environment.

Many new technological applications will be implemented throughout the firm's operations, and the majority of personnel will be affected. This presents the element of change. Many people resist change, often because they lack the knowledge needed to change effectively. (Gunn, 1986) In addition, implementation of CIM involves operation of computerized equipment, and many people fear computers or at least feel uneasy about using them. Only education and training will overcome these human problems at all levels of the company.

Too often, management makes an initial commitment to education and training, but when the need arises, the funds have been diverted to apparently more urgent uses. It is important to emphasize and reemphasize that without education and training, the CIM program will not achieve the goals expected of it. Like planning, education and training require the commitment of substantial resources. However, performing these processes in the midst of or after implementation of the technology is far more expensive and may jeopardize the program.

Investment Justification

Investment barriers are perhaps the most common reason for companies to avoid investing in CIM technologies. Most justification procedures currently in place concentrate on cost reduction only. They fail to consider the revenue-generating potential provided by improving the overall effectiveness of the operation. (Production Management, March 1984) Therefore, senior managers must reexamine their investment justification procedures.

Owing to the scope and nature of CIM programs, the underlying investment justification is commonly the most difficult aspect of initiating a program. CIM programs differ from traditional capital investments in various ways which must be considered when performing an economic justification. These include:

- The benefits of CIM are not limited to the initial impact of the equipment. Advantages resulting from the integration of equipment and systems continue to be identified as the program proceeds. These opportunities for additional benefit arise because integration allows a more dynamic response to changing competitive situations.
- CIM costs decrease with time owing to the upward compatibility of the hardware as well

as its rapidly improving price:performance ratio.

- The greatly leveraged flexibility of the manufacturing facility affects the way the company does business with its customers and suppliers.
- CIM increases the effectivenss of communications and thereby decreases the time scales with which the company responds to new opportunities and problems.
- CIM affects the people in the organization, requiring new skills, attitudes, and measurements. This requires that management anticipate human resource development and organizational changes at a very early stage in the program. (Savage, 1986)

Consideration must be given to all the costs and benefits of the CIM program. This consists of making comprehensive and sufficiently long-term estimates of costs, investment in facilities, and revenue. Doing so may very well mean attaching a hypothetical value to a qualitative benefit.

It is necessary to advise senior management to revise their company's approach to investment justification when considering investments in CIM. Rather than applying case-by-case analysis to individual CIM technologies, management should view the entire program from a broader strategic perspective. Justification procedures must focus on the relationship of the CIM program to the firm's competitive position.

The Ongoing Nature of Management Education. It is expected that once the foregoing phases of management education have been completed, senior management will have a good overall grasp of the concept of integration and of what is involved in undertaking a successful CIM program. However, management education is an ongoing process. It is further proposed that senior managers be provided with biweekly reviews of progress as well as briefings on the significance of each step being undertaken throughout the CIM program.

The natural resistance of all people to change can be overcome by appropriate education. Such education is especially appropriate for senior management because without their support, the program cannot succeed. (Bennett, 1985)

PROGRAM ORGANIZATION

The foregoing section stressed the importance of senior management involvement in the initiation and completion of any CIM program. However, many other individuals must also be considered during the planning phase. The concept of integration applies to the human aspect of the business as well as to its activities. Every employee in the company must have a stake in the program. This section proposes that an integration, or CIM, program must start with the organization of the company.

The human side of CIM is often neglected. It is people who devise and implement strategies. It is people who make systems and businesses work. (Gunn, 1986) They therefore should command strong attention early in the CIM program. There are three essential aspects to which this attention should be addressed: organization structure, performance evaluation and rewards, and staffing. All three areas are very important; the first may cross the boundary from CIM planning into corporate organization.

Organizational Structure. An organizational structure conducive to CIM planning and implementation must be erected. In some cases, this involves the creation of a top-level post, usually a vice presidency, so that one individual has the charter to plan for CIM and to monitor progress of the planning and implementation efforts. In cooperation with this individual, line managers will have the responsibility for obtaining the agreed-upon goals in their respective areas.

Performance Evaluation. It is often necessary to refocus the company's incentives, rewards, organizational structure, and performance and measurement systems so that they collectively reinforce future CIM goals and integrate them with current practices. A major portion of a well-designed CIM program involves human resources issues: significantly increasing employee motivation for the planning and implementation of CIM, improving communication, staffing, and education and training of personnel.

Staffing, Staffing is a key consideration in any CIM program. New personnel-acquisition programs frequently have to be devised to hire the people to plan for and implement CIM. A major commitment on the part of the company is often necessary, especially to the functions of manufacturing engineering and information systems. Instead of the usual current 5:1

to 10:1 ratio of design engineers to manufacturing engineers, a company may find it necessary to target a ratio of 1:1 to overcome years of neglecting the manufacturing process. Creating a human resources skills staffing plan is especially important, for it often takes years to find, hire, move, and train new company employees. (Gunn, 1986)

This section proposes a methodology for addressing the organizational concerns related to CIM planning, including the organization of personnel for the planning process, integration of the human resources of the business, and the education and training of company employees. The program organization stage of CIM planning focuses primarily on the organization and management of a CIM planning task force and the preparation of all employees for participation in the CIM program at their levels of responsibility.

It is proposed that organizational responsibilities for the CIM planning program be appointed early. The proposed organization of the CIM task force comprises three levels:

1. The top level consists of the steering committee, which has overall responsibility for the entire planning and implementation

effort.

2. The next level consists of the project team leaders, who are responsible for the day-to-day management of the entire CIM effort.

3. The third level consists of the project team members, who will actually be performing the required tasks; these individuals are employees who will be affected by the possible changes and who are assigned task responsibilities based on their experience.

Senior Management Steering Committee

It is proposed that in order to instill top-down planning, the first activity be to form a steering committee composed of senior management to provide direction and commitment toward the development of CIM as a business strategy. This Committee should be composed of (1) the chief executive officer or president and (2) all vice presidents in charge of major organizational functions. (Punwani, 1983)

The steering committee should be headed by the CIM champion described in the section of program initiation. Ideally, this would be the chief executive officer or president. Other good candidates for heading the CIM planning effort would be the vice president of manufacturing or the chief information officer, if the latter individual has senior management status. Formation of a steering committee spreads the responsibility for the CIM program throughout senior management; however, the head of the committee will have the explicit responsibility for maintaining progress and keeping top management involved. All major issues will be discussed by the steering committee as a whole, and all decisions will be signed off by each member. One result of this policy will be to achieve cross-disciplinary departmental communication.

A major tenet of this thesis is that a successful CIM program must begin from the perspective of management of the entire enterprise. Charles Knox, President of Knox Associates, has said, "If policies do not come from the top down, politics will come from the bottom up." The prevalence of a management style known as "foxhole management" testifies to the role of politics as a driving force in industrial organizations. (Savage, 1985)

To achieve a more interactive organization, management must change departmental charters so that the boundaries between functions are less strictly delimited. Each department will be expected to seek more information from other departments with the goal of improving overall company performance.

The essential task of the steering committee is to maintain a strong sense of business focus and direction while organizational functions operate in a more parallel and interactive fashion that has generally prevailed in U.S. industry. Senior management cannot afford to remain out of touch with the goals that drive the everyday decisions of functional managers. A vigorous dialogue is necessary. To set the context, it is essential that the steering committee articulate firm goals to provide all participants with a sense of direction and vision.

The CEO and the steering committee have a vital role to play in achieving CIM. It is proposed that their principal tasks consist of (1) setting business strategy for the ensuing five years, (2) redefining corporate policy to facilitate greater networked interaction between the various functions of the company, and (3) to organize and provide overall support and direction for a task force capable of performing the CIM planning cycle. By integrating the efforts of individuals with various backgrounds and responsibilities, the steering committee will set an example that will facilitate the company-wide effort of integrating human resources. It is proposed that the next step be the organization of the planning task force.

Organizing a Project Team

Project Team Chairman

The first task in the formation of the task force, or project team, is to identify the chairman. This person will promote a team approach melded by group decision making. It is necessary that the chairman be a business-minded technological generalist with a thorough understanding of all concepts related to CIM (Punwani, 1985). This understanding may have predated the initiation of the planning cycle or may be acquired at the outset, before the project team is selected. The project team leader will be solely responsible for managing the CIM planning program at the tactical level and must therefore be given the authority to delegate tasks to professionals within the company as well as to middle and functional managers.

Project Team Leaders

Once the chairman has been selected, the project team leaders must be chosen by the chairman with the support of the steering committee. Together, the committee and the chairman will identify the skill pool from which the team leaders, and later the team members, are to be drawn. The organization, size, and personnel requirements of the project team will depend on the company--the size and complexity of its organization and the extent to which its activities have already been computerized.

It is proposed that the team of project leaders be composed of middle and functional level managers together with professionals who have the authority to manage projects in their particular area of specialty. This team will be responsible for the daily management of the entire CIM planning effort and, later, for its implementation. To successfully integrate the entire business cycle, from customer quotation to shipment of a finished product, project leaders should be selected from a broad variety of disciplines within the company.

It is proposed that team leaders be selected from the following areas according to which functions are critical to the company's operations (Punwani, 1983):

- o industrial engineering
- o management information systems
- o design engineering
- o manufacturing engineering
- o advanced technologies
- o materials management
- o manufacturing
- o purchasing
- o finance
- o accounting
- o sales
- o marketing
- o quality assurance
- o human resources
- o distribution

In choosing team leaders, the steering committee should concentrate on selecting the company's hardest-working, most motivated individuals from each discipline. Middle managers and department heads who are asked to suggest individuals for special projects must be advised that it is their resonsibility to provide a leader of high calibre, not an employee who will not be missed from his or her department. It may be advisable to evaluate middle managers on their ability to streamline operations in their areas by utilization of the new technologies and the associated integration concepts.

Participation by Outside Sources

In many cases, it may be advisable to include representatives from sources outside the company--

universities, professional associations, and consultants--to broaden the base of experience available to the project team in some areas of the CIM program. These outside sources may also bring with them an unbiased attitude and a fresh view of company operations. Once the skill level pool within the company has been identified, the project team chairman will be able to identify the areas in which outside consultants may be required and to begin searching for the appropriate individuals and organizations.

Project Team Members

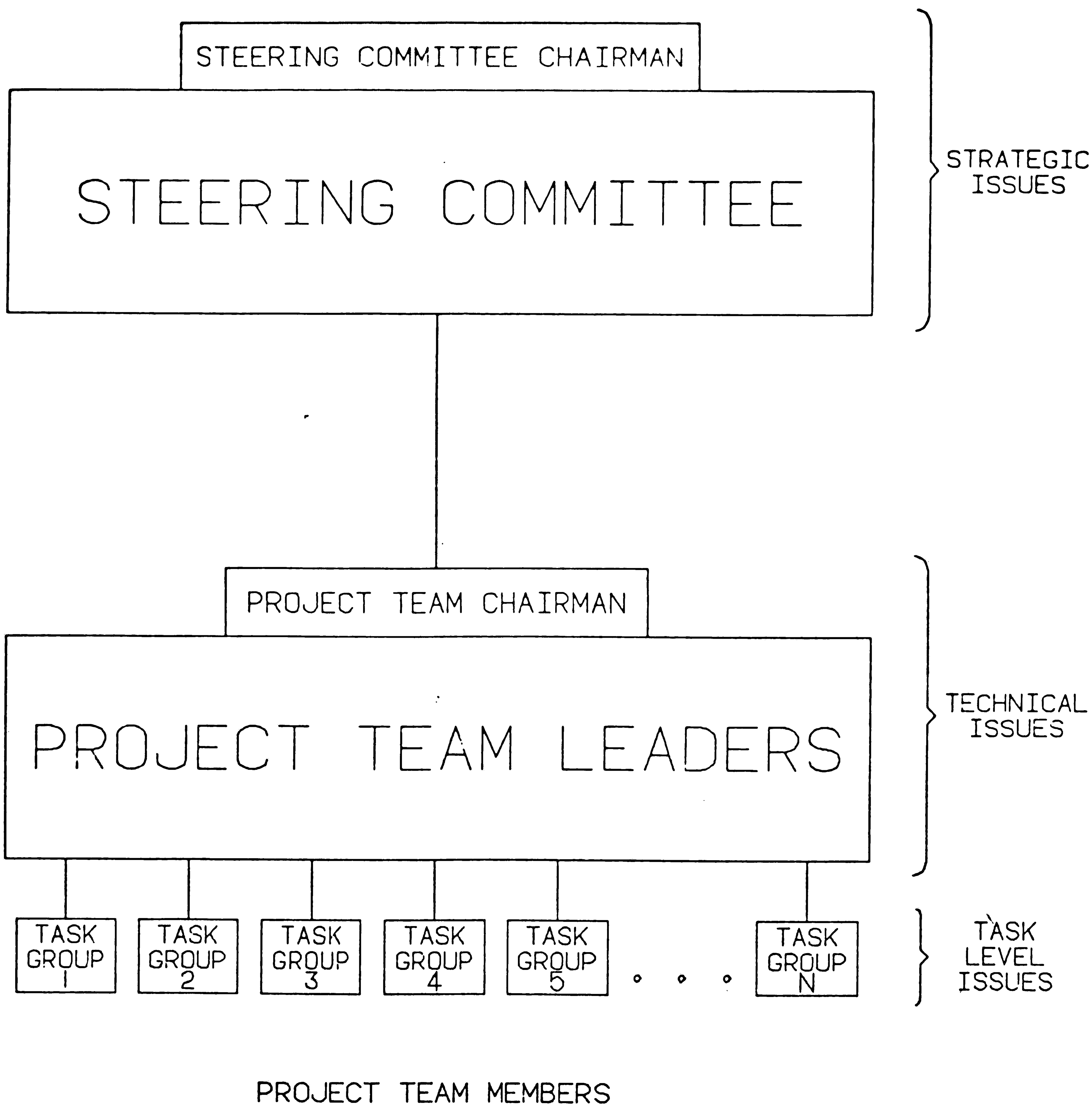
It is proposed that the next level to be addressed in assembly of the project task force is the project team membership. In many cases, these individuals will be the eventual end users of the CIM technologies and applications. Team members will be performing a majority of the required tasks under the guidance of the project team leaders.

The inclusion of end users in the CIM planning program serves two purposes. First, they will be able to provide valuable insight on how the present operation actually functions and to suggest improvements. Second, inclusion of end users in the planning process provides them with a sense of ownership. No modernization project involving change in everyday routines will succeed without the support of the end users. Participation by these individuals in the planning stage will promote user acceptance and improve the chances for success.

Organization of Task Groups

As previously described, the project team will be composed of (1) a chairman, (2) project leaders who are technical experts and members of management, and (3) end-user representatives from critical areas of the company's operations. This team will be further organized into task groups. It is important that these groups be organized cross-functionally, i.e., not along strict functional lines such as engineering systems, financial systems, and so forth. Cross-functional structuring proceeds in a task-oriented manner: those who seek out new technologies, those who develop them, those who install them, and those who provide end-user support once the technology has been implemented (Figure 2) (Snyder, 1985)

Figure 2: Task Force Diagram



Individualization of the Project Team

The actual composition and organization of the project team will vary according to the needs of the particular company and the size of its operations. The three-tiered approach presented here is designed for larger corporations having perhaps 1000 employees or more and a need to integrate information flow among all functional areas. A small company of perhaps 200 employees will not need a three-tiered team organization, especially if there is no middle management level and the end users <u>are</u> the technical experts. The crucial feature of the project team is involvement by all levels of the company from senior management down to those who will actually be using the technology daily.

The formation of a task force to address CIM facilitates the major adjustment in departmental charters and work assignments that will be necessary to support a networked organization in which information will flow freely among the various functional groups. It is this integration of information flow and inmproved intraorganizational communications that will permit the company to perform its business activities more effectively.

Having established a task force, the top-management steering committee will remain responsible for keeping CIM planning activities flowing and on target. In order for project teams to be effective, they must have direction and a set of goals provided by those individuals who develop the business strategies. Therefore, the next step is for the steering committee to establish a preliminary set of strategic goals for the company.

Formulating Preliminary Strategic Goals For the Company

The key to a successful CIM program, as with any complex operation, is a good plan. This plan must be strategically oriented and must incorporate CIM specifically. It must state specific goals derived from the perspective of improving the company's competitive effectiveness over a span of five to ten years under current and projected market conditions. The CIM advocate must emphasize to senior management that such a CIM-oriented strategic plan is a vital prerequisite for any serious planning of the CIM program.

Strategic Aspects of the Plan

Often, senior management responds to a request to compose a list of company goals and objectives with, "We know what our business goals are, so why should we go through this exercise?" Alternatively, they may refer to a company business plan that was formulated months or years earlier. Many companies have a business plan that is routinely updated every year or two. This plan is a good place to start, but it is not sufficient in itself because it has generally not been developed with integration concepts in mind. The existing business plan can be viewed as groundwork subject to further review and reorientation.

A CIM-oriented strategic plan will need to describe the general nature and intent of the business, the served markets, the products that are currently in production, and the products that are in the product planning cycle. It will describe the organization and facilities, including integration aspects, needed to excel in producing, installing, and providing field support for these products with the objectives of customer satisfaction and loyalty.

The present and future needs of the business must be taken into account, with CIM as an integral part of the plan. Among the questions that must be answered in order to develop a sound business plan are:

- o What are the corporation's strategic business goals and objectives? Determining the direction of the corporation will ensure that CIM is implemented in a manner compatible with and complementary to the anticipated changes. As the CIM program progresses, this process should be periodically repeated.
- o What factors will be key to the success of the corporation in the future? The answers to this question define the minimal requirements of the CIM program and also provide direction for future design considerations. For example, if labor costs are rising so rapidly as to threaten the company's competitiveness, cutting back labor costs is a key factor in future success. One way to accomplish this is through automation.
- o What is the evolutionary path of the company's product lines? The purpose of this question is to ensure that the CIM program will be compatible with possible future products of the corporation. The answers will help, for

example, to identify where flexibility needs to be built into the system.

Too often, business planning focuses on traditional concepts of business strategy such as vertical integration, production technology, plant location, capacity, production systems, labor force composition, and similar matters. Many executives tend to view these as one-time decisions that, once made, need little reconsideration beyond perfunctory review.

Although traditional views of manafacturing strategy are important, they fail to consider day-to-day competition--the manner in which companies are measured in the marketplace as well as in their financial reports. In football, a team's blocking, kicking, passing, tackling, and running must be good in themselves but must also be blended into an overall competitive resource. In manufacturing, analogous measurements of performance include such fundamentals as lead time for new product development, cumulative manufacturing lead time, inventory turns, quality levels, total cost per unit of production, and product innovation. (Gunn, 1986)

Goals such as increasing sales volume, market share, and profit are at once too general and too specific. The basic questions in formulating goals are: (1) How can we improve the company's effectiveness as a business? and (2) How can we improve its overall competitive position? Senior managers need to pay continual close attention to strategic objectives that address the basis of competition in their particular industry. The constant focus of their thinking must be a search for competitive advantage in those fundamentals of business operations by which they are measured in the real world. Ultimately, companies must compete on the basis of providing their products and services effectively in the modern marketplace. (Schneiderman, 1981)

Focusing on these fundamentals will allow senior management to determine an initial business strategy by which to guide the planning stage of their CIM program. The CIM task force will then be able to plan the CIM program with a holistic view of the organization and its long-term objectives. More specifically, the task force will be able to work towaard a long-range blueprint for CIM implementation. (Elavia, 1985)

Advantages of Formal Planning

It has been proved that formal planning based on a long-term outlook improves the effectiveness of an activity. Information systems activity has served as an example of improved performance through formal planning with consideration of formal needs. McKinsey and McFarlen, two well-established experts on information systems, have conducted studies that demonstrating that information systems developed in companies that utilize long-term planning are more effective than systems developed in companies without such plans. The results of these studies are applicable to the closely related area of CIM planning, since both disciplines deal with the company-wide dissemination of information. (McFarlen et al., 1983)

Formal planning utilizing long-term perspectives can accomplish the following: (1) offsetting uncertainty, (2) improving operational economy, (3) focusing on objectives, and (4) providing a device for the control of activities.

The Strategic Planning Process

The CIM-oriented strategic goals that will drive the CIM planning effort should be formulated in a series of meetings involving major shareholders (so-called "stakeholders") in the company, executive management, and key supporting managers. The formulation process need not be lengthy or elaborate. All that is required is that the participants discuss major company goals and objectives, establish a single set of complementary goals, assign the goals hierarchical values in terms of their relative importance to the company's competitive success, and sign off on this list. With this information as background, serious planning for the CIM program can proceed. (Ness, 1985)

Once the strategic plan has been formulated, the tactical plan can be developed. This tactical plan will break down eash broad business objective into a set of functional business objectives that must be addressed in order to realize the overall strategic goals. The CIM plan is developed from the company business strategy and is part of the tactical plan. The CIM program will therefore address the critical business issues of the company operations.

Developing Tactical Objectives

With the overall strategic goals in place, the two upper levels of the project team, or task force, can develop tactical objectives necessary to the achievement of the strategic plan. At this point, the strategic goals must be broken down into a results-oriented, detailed list of requirements. These objectives will set forth the changes that are necessary to meet general goals such as increased sales volume, market share, or profit.

An important point to stress in regard to the proposed planning process is that the business strategy that drives the CIM program cannot be formulated and subsequently ignored. A business strategy consists of a firm's integrated approach to a constantly shifting external environment; that is, it is an ongoing process.

The strategic goals initially set by the steering committee identify a general direction at the outset of the CIM planning cycle. However, the strategic plan itself should be constantly updated throughout CIM planning and implementation and thereafter in response to changes in technology, costs, and global competitive conditions. The initial exercise in developing business strategy will have encouraged strategic thinking by senior management in regard to the company's overall business goals. This kind of strategic thinking must then be applied to CIM planning.

Once strategic goals for the business have been formulated, they must be communicated to the individuals selected to lead the task force, or project team. A thorough understanding of CIM concepts is prerequisite to the team leaders' incorporating those concepts into a set of tactical objectives.

Education of the Project Team Leaders

The actual tactical planning of the CIM program requires that the project team leaders become thoroughly familiar with CIM concepts as well as such areas as CIM planning and the associated technical issues. The project team leaders will be developing the tactical plan under the guidance of the steering committee and will be responsible for performing the actual activities that will drive the CIM planning effort and eventually the program itself. Just as the education of top management began with integration, so too will the education of the project leaders. The main difference will be that education of the project leaders will place greater emphasis on the technical aspects of integrating a company's organization and operations. Nevertheless, it is proposed that the project leaders' education begin with the basics.

Integration As the Underlying Objective

Integration, as presented earlier in this thesis, is the underlying objective to be achieved by assimilating new technology that will assist in linking all key areas of the business. The project leaders should be made aware that through integration, their company can maximize its effectiveness as a market competitor. True effectiveness will be realized only when all business activities, and the resources used to perform these activities, have been logically integrated through the sharing of a common base of information.

The Information Infrastructure. This common base of information can be thought of as a company's information infrastructure. In the past, this infrastructure has had both formal and informal components. Of these, the informal infrastructure has been less well understood. It is maintained in the minds of the people who carry out the functions of an enterprise and consists of the decision rules made by individual employees and the undocumented procedures that employees follow in order to perform their specific tasks. (Young & Mayer, 1984) Despite its being poorly understood, this informal infrastructure has heretofore been the key to maintaining the operation of manufacturing-oriented enterprises. (Young & Mayer, 1984)

Concurrently with the informal infrastructure there exists a formal infrastructure. This has consisted mainly of manual paper systems for transmitting information between functional groups and storing that information within the company. Recently, companies have been building formal infrastructures, sometimes in the form of computer systems, to facilitate sharing of information by many individuals within the enterprise. A major task for the project team will be to minimize the informal infrastructure and improve the capability of the formal structure to provide a common base of information utilized by all functions of the business. (Schneidermann, 1981)

Topic Areas for Education

To accomplish this task, the project team leaders will need to acquire knowledge about available CIM technologies and concepts related to collection of data, compilation of information from that data, and distribution of the information to the necessary functional areas in a timely and cost-effective manner. A few of the areas in which selected team leaders will have to be educated are new information systems strategies, networking, database management, data collection devices, and decision support systems. The particular educational requirements will vary considerably depending on the company, the complexity of its operations, and the backgrounds of the individuals who are chosen to lead the project team.

A Proposed Scenario for Educating Team Leaders

Many possible approaches exist for accomplishing the task of educating and training team leaders. Experts can be brought in as educational resources for the company. Team leaders can be sent to seminars on CIM technologies. Regardless of the approach or combination of approaches used, motivation is a crucial concern. The project leaders must firmly believe that their participation in the CIM program is critical to the company. If sufficiently motivated, individuals may begin to pursue their education on their own time as well as at work, thereby greatly enhancing the program's probability for success. Senior management can greatly facilitate motivation through close involvement with the CIM program and by providing opportunities for career advancement to those individuals who excel at the accomplishment of their CIM planning tasks.

Utilization of Seminars. It is proposed that company-sponsored CIM education be initiated by sending project leaders to seminars on CIM-related topics. Seminars that stress the importance of CIM and CIM planning are especially valuable at the outset. Utilization of seminars has two major advantages: (1) Project leaders are removed from the daily distractions of the plant site and allowed to concentrate on learnings, and (2) project leaders will be learning from top experts in the field of CIM and will later be able to draw on their seminar experiences when instructing their task groups regarding CIM principles. (Appleton, 1985)

Later, as specific projects are undertaken, team leaders should be sent to technical seminars on specific technologies. Education related to CIM planning should encompass the following areas:

- Project management techniques
- Performing an "As Is" analysis (see following section)
- Methodologies for conducting factory analyses

- Methodologies for conducting information flow analyses
- Development of cost models for financial analysis
- Performing a needs analysis
- Evaluating different business functions for improvement potential
- Development of conceptual designs for critical functional areas utilizing current technologies
- Development of an implementation master plan (Elavia, 1985)

Additional Educational Techniques Project leaders may be sent to visit companies where successful implementations of CIM exist, to conferences on CIM topics, and/or to technology showcases. Outside consultants from industry or the universities may be utilized for education or for technical assistance. Apparently minor strategies can be helpful. For example, employees may be encouraged to dedicate a few hours of paid time to reading trade journals, thereby amassing literature databases and case examples. Public domain information is available from various federal projects, including NASA's IPAD, the U.S. Air Force's ICAM, and the Advanced Manufacturing Program of the National Bureau of Standards. (Bravaco, 1985) The project leaders should attempt to utilize as many resources as possible to learn about CIM and to keep abreast of developing technologies.

Basic Principles Underlying CIM

In addition to introductory and technical education, the project leaders must have an understanding of the basic principles that underlie computer-integraated manufacturing. They must be made aware that the integration they are striving to attain evolves from a management process, not from a set of technologies, a system, a product, or a single project. (Productivity International, 1981) Their basic goal will be the effective direct executive control and management of information, time, and materials through the application of CIM and integration concepts.

To accomplish the objective of executive control, the project team leaders and all individuals functioning under their direction should understand that:

- The CIM program must be opportunity driven rather than technologically or functionally driven.

- The program must be user based rather than user oriented.
- The program must be dynamically structured rather than rigidly structured.
- The program must be results oriented, not process oriented.

It is important to note that these principles may contradict previously held conceptions of CIM. Nevertheless, the team leaders must adopt this attitude.

The Importance of Standards

It is necessary that the importance of standards be stressed at the outset. Their importance will become increasingly apparent later in the program in relation to such issues as types of equipment, communications/computer hardware, and information-exchange protocols.

To achieve computer-integrated manufacturing, companies must have the capacity to exchange information freely and reliably between different makes of computers, machinery, and equipment. They must also maintain sufficient flexibility to implement partial upgrades and replacements of integrated systems in response to new technologies.

Until recently, these goals have been expensive and technically difficult to achieve, but their attainment can be facilitated through the use of standards. These are vendor-independent, device-independent specifications for capturing data and transmitting it between systems; for physically connecting different types and makes of equipment; and for a variety of issues related to system configuration, operation, and support. (Conkol, 1985) Project leaders must be made aware of the benefits associated with the use of standards and must have a good understanding of the concept of standardization.

Standards can be viewed at two levels, industry and corporate. Industry standards are adopted by vendors and implemented in the design of their products, including software, hardware, machinery, and equipment. Corporate standards are adopted by users and are implemented in a company's purchases of vendor equipment and in the specifications of internally developed systems. Corporate standards are helpful in several ways:

- They speed the transfer and diffusion of CIM technologies within the firm.

- They facilitate training of staff and support of systems in place.
- They shorten procurement cycles by reducing the number of technical issues involved.
- When properly applied and widely used, they lower the cost of CIM.

These benefits are especially important for those developing CIM plans in multi-plant and divisional firms. In setting corporate standards, project leaders may draw on five potential sources: (1) internally developed standards, (2) vendor-specific standards, (3) de facto standards, (4) industry-specific standards, and (5) industry-universal standards. (Savage, 1985)

Internally Developed Standards. These are akin to company policies and procedures. For example, some firms find it useful to standardize part numbering across plants and products. Specified practices such as this simplify the task of designing CIM systems.

Vendor-Specific Standards. It has been traditional practice to standardize on certain vendors for certain tasks and systems--for example, using DECNET to link engineering and production or MacNeal Schwendler's NASTRAN for engineering studies. This vendor-specific approach risks a poor fit to the company's needs and may limit a company's options. (Savage, 1985)

De Facto Standards. These standards emerge from the marketplace in response to a given vendor's or product's market share. For example, the PC-DOS operating system is a de facto standard in microcomputing. In adopting a de facto standard, the buyer must be confident of its durability. (Savage, 1985)

Industry-Specific Standards. These are the easiest to adopt. There may be no choice. For example, the automotive industry adheres to standards set by its Automotive Industry Action Group (AIAG), whereas mechanical industries adhere to MAP for transmitting data between machines and computers. (Savage, 1985)

Industry-Universal Standards. These may originate in a single industry or trade group, becoming universal because of wide appeal and crossing industry lines. A typical universal standard is RS-232 governing low-speed, short-distance connections between equipment, the lowest level of computer integration. Standards of this kind come imbedded in equipment and are primarily useful to vendors. Corporate standards employ them for networking of different systems.

The interdependence of various functions of a business necessitates that standards for one activity be cross-checked for compatibility with those for related activities. Before putting new standards into effect, it is necessary to ensure their workability with existing systems and equipment. (Savage, 1985)

Planning a Company-Wide CIM Education Program

Once the steering committee and the project team leaders have assimilated the basics, the remainder of the company employees must be involved in the CIM program, including its planning. It is these individuals who will be using the implemented technologies and new procedures in day-to-day operations. Their cooperation is essential. Therefore, they should be made aware of the CIM activities that will soon be taking place and assured of their role in these activities.

The steering committee and the project leaders should formalize plans for the introduction of the CIM program to all company employees. The human resources department should play a major role in presenting the CIM program in a manner that will not arouse fears of job loss and total change.

The approach proposed in this paper is a series of informal, informative meetings with employees. Special meetings may be set up for this purpose, or an existing employee meeting structure can be utilized to inform employees about the CIM program. Such informative meetings should be conducted on an ongoing basis, for example, when a new major stage of the CIM program is about to begin or before changes in operating procedures are implemented.

Promoting Company-Wide Involvement

Everyone, from the chief executive officer to the hourly worker, needs to feel a sense of ownership for his or her piece of the CIM program. (Savage, 1985) Company-wide employee involvement from the beginning will serve to reduce resistance to change. It increases the likelihood that end users will assume psychological ownership of the changes, especially if they have been involved in development of the specifications for chnage. Conversely, the greater the feeling that the program is serving the needs of only a few groups or particular areas, the less cooperation can be expected and the less integration will be achieved.

Integration of the entire business into a more effective operation is the ultimate goal of any CIM program. To achieve integration of this kind, the people, their roles, and their methods of operation must be integrated as well. This will require cooperation on a broad scale between all factions of the company, and the chances of obtaining this level of cooperation are greatly enhanced if all company employees are involved from the beginning. (Snyder, 1985)

One of the most effective means of promoting cooperation is through a company-wide education program. An added benefit of education is that it reduces resistance to change. People naturally fear what they do not understand, and a change in accustomed routine represents the unknown in the minds of the individuals concerned. The result is resistance. On the other hand, if the proposed change is discussed with employees, the reasons for implementing the change are explained, and if employees have input into the change, resistance can be minimized.

The benefits of education are intangible, and consequently the importance of its role in appropriately preparing the workforce is rarely recognized. However, if senior management acknowledge that success in building the future into their company depends on people, not on machines or systems, they will make the investment in time and resources to implement a company-wide education program.

Many employees will be making a transition from being production workers to being information workers--to doing different tasks that require new skills. Because experienced people are hard to find, it is to the company's advantage to motivate and train the existing workforce. The employees will have to understand their new roles and support the change.

To a foreman, machine operator, or production control clerk, computers may seem threatening unless the concept of using new technologies is appropriately presented. This means not only education in the use of new technologies but a strong presentation of the employee's own stake in the company's survival and growth. Making employees aware that improving their company's effectiveness helps ensure their jobs is part of the educational process, which must be tailored to the individual needs of a particular company's employees. (Gunn, 1986)

Costs Involved in Employee Education

Senior managers may not be prepared for the financial commitment involved in a company-wide education program. Once the cost data are presented to them, they may be reluctant to initiate or continue with such a program. Upper-level managers must be aware of costs from the outset and must also be able to weigh these costs in relation to the benefits, some of them intangible, that a comprehensive retraining effort provides.

Experience shows that companies should be prepared to spend in excess of $1000 per worker per year in an ongoing education and retraining program to support the technical and cultural change necessary for CIM. Such an ongoing program generally represents from 5 to 10 percent of the capital cost for CIM equipment. (Gunn, 1986)

One means of keeping training costs reasonable is maximal utilization of project leaders as instructors in their expertise. This is one benefit of providing the highest quality CIM education to the project leaders: the cost of educating them can be leveraged against the cost of the entire education and retraining program. There is an added benefit to utilizing project leaders as instructors: the awareness that they will be teaching CIM concepts to others promotes concentration and commitment to learning them thoroughly.

The Role of Education in Promoting Integration

As the CIM planning cycle continues, specifically the "As Is" analysis discussed in the subsequent section, the various functional areas will better comprehend how their activities affect other departments. Realizing how costly mistakes and limited vision can be as they ripple through other departments tends to reduce functional rivalries and "turf protection." For example, most companies do not have a firm grasp on the cost of engineering change orders, which is generally several times higher than anticipated.

Company personnel must realize that functional thinking, organizational thinking, and the organizational structure itself can prevent managers from seeing the full range of opportunities afforded by CIM technology. (Production International, 1981) This type of thinking tends to promote a "tunnel vision" effect in which functional employees, including the manager, focus only on status quo performance of their discrete function instead of investigating ways in which that function can be improved to enhance overall business effectiveness.

CIM technology, because of its flexibility, provides the potential for cost-effectively streamlining functional activities and providing more timely and accurate information about them to the company's decision-makers. In this way, CIM technology becomes strategic. Its real value transcends manufacturing or any single function. For this reason, managers must view CIM technology from a broader, company-wide perspective, and this perspective, as well as benefits to a manager's specific function, must be emphasized in employee education. (Production Engineering, 1985) Once functional managers are aware of the full implications of the CIM program, they must commit themselves to it and assume the responsibility of improving the effectiveness of their particular function.

Many companies fail to obtain this understanding and commitment to the CIM program from their managers. Doing so is a time-consuming process of human learning that cannot be forced to fit artificial deadlines. It must proceed at its own pace. (Savage, 1985) However, if it does not occur during the planning cycle, it will have to occur in the implementation phase. In that case it will be a much more difficult and costly endeavor.

Developing Guidelines for Project Management

At this point in the program organization stage of the CIM planning cycle, the managers and decision-makers of the CIM task force have been identified and organized, the basic strategic goals of the company have been formulated, the project team leaders have been given a general education with which to begin CIM planning, and an education program for the entire company has been set up. It is proposed that the final steps in this stage be the development of formal guidelines for project management.

Creating a Structured Set of Procedures

Development of project management guidelines may be initiated by creating a structured set of procedures to specify the manner in which individual projects will be approached and managed.

The Importance of Standardizing Procedures. Consistency is the key to both quality and integration, and specifying project management procedures will ensure consistent management. Once project management procedures have been adopted by the task force, they will be used as structured approaches to defining requirements and conducting specific CIM projects.

These procedures are akin to internally developed corporate standards such as those presented in the section on educating project team leaders--for example, a company-wide part-numbering system. The benefits associated with establishing standard procedures are similar to those for adopting standards in general. Standards are critical to ensuring integration in a CIM program.

A typical set of project procedures might identify the following items at the outset:

- The appropriate team leader
- A set of key tasks to complete
- The project team, or task group, members
- Estimated manhours by specific personnel assigned
- Planned task-completion dates

Consensus in Decision Making. These and other decisions should be established by group consensus. This implies the most important management aspect of a

CIM program, the decision-making procedure. The project-management guidelinees must include a description of the decision-making procedure utilized by the steering committee and the project team or task force.

The use of group consensus to make important decisions will (1) ensure that all relevant issues will be discussed and (2) impart a sense of fair play through majority acceptance. Research in the area of group dynamics has demonstrated that consensus should be reached by at least 75 percent of the total group before a decision is passed. In cases where a critical decision must be made and majority consensus cannot be reached, the chairman of the group will preside. (Sun, 1985)

Leadership Responsibility and Authority

The next issue to address in formulating project management guidelines is the responsibilities and authority of the project team leaders. This issue should be resolved by group consensus of the steering committee members. Each CIM cycle can be broken down into project areas and further component tasks in the same manner as the planning cycle has been broken down in this thesis. Similar works that develop approaches to other cycles of the CIM program should be consulted in developing a company-specific plan of action. Once the action plan has been developed at the management level, specific responsibilities can be assigned to the project team leaders. The authority of each individual project leader can then be assigned by the steering committee in accordance with company policy.

Maintaining Project Control

The two major aspects of project control are (1) collection of information on individual projects and (2) interpretation of that information. Information must flow from bottom to top; that is, information collection begins at the project team (task force) member level. As the information moves toward senior management, each level summarizes the reports of the level below it and adds its own status information.

It is proposed that the project status first be discussed among team members in task group meetings. The information summarized at these meetings should then be discussed and augmented during meetings of the team leaders before being presented to the steering committee. In this way, senior management can monitor progress and remain involved with the program. Their input will be required whenever key projects are completed and when projects are not meeting deadlines.

The establishment of appropriate mechanisms for periodic reporting ensures sound communication among top management, project team personnel, and middle managers. Management will be promptly alerted to the possibility of delays in critical projects, enabling them to avoid major setbacks by allocating additional resources or replanning the sequence of events.

A formal reporting procedure established by the project management guidelines will provide a feedback mechanism for the control of the CIM program. Documentation on the initial planned course of action is also required for the effective control of the program. Management will need to compare the actual with the planned completion of events in order to make the necessary adjustments.

Other information that should be documented throuhout the program includes assumptions made in regard to technical consideratrions and financial analysis. This documentation can later be employed in establishing a performance rating on projects. Projects that result in savings or improvements above or below the expected levels can be altered, remaining projects can be reevaluated in the light of experience, and new priorities can be set if necessary.

Documentation on projected benefits and task completion dates is not sufficient for establishing performacnce measures, however. The real measure of performance will be the company's success in achieving its strategic goals. Evaluating strategic success will not be a simple task, because accomplishment of a strategic goal may require the successful implementation of a number of CIM projects. The CIM planning task force must therefore prepare a charter to follow as the planning program evolves. This charter will direct the development of a hierarchical set of goals and objectives designed to achieve the strategic business goals.

A well-defined project management approach will set the stage for managing and controlling the various activities required to develop the CIM master plan and, eventually, to successfully implement an effective CIM program.

Objectives Achieved by Project Organization

The project organization phase of the CIM planning cycle is its last preparatory phases. It consists of

(1) formation of a CIM planning team, or task force, (2) establishment of strategic business goals that will drive the CIM planning effort, (3) planning of a company-wide education and training program, and (4) establishment of project management guidelines. The purpose of this phase is to build a CIM task force and to establish the management structure to network not only technology but the organization's people into an effective, flexible, responsive organization. (Savage. 1985)

It is proposed that the organization of the CIM program according to the pattern specified in this paper will:

- Establish accountability and responsibility.
- Encourage company-wide acceptance of the CIM program.
- Provide a set of CIM directives established by consensus
- Provide a system for the allocation of tasks, responsibilities, and authority.
- Provide a method for coordinating and controlling project efforts.
- Provide a means for communication within the project group.

- Define and assemble the required skills at the right time.
- Provide for end-user representation and participation in planning and implementation.
- Provide a method of communicating between end users and management.
- Provide a clear separation of the technical and administrative skills needed in the project.

The underlying philosophy presented in this section is that CIM can be successfully achieved only through a blending of a wide variety of technologies, procedures, policies, and imaginative leadership. (Savage, 1985) The groundwork for a successful CIM program will have been laid at the completion of the project organization. At this point, the organization will be ready to undertake the actual task-group activities that will eventually generate the final CIM master plan.

"AS IS" ANALYSIS

The stages of the CIM planning cycle discussed in the foregoing sections have dealt with preparation. It is proposed that actual planning begin with the process known as an "As Is" analysis.

The concept underlying computer-integrated manufacturing is the elimination of inefficiencies in the operation of a business and the streamlining and integration of operations with the assistance of computer technology. It is proposed, therefore, that the actual planning of the CIM program begin with an examination of existing procedures. The purpose of the "As Is" analysis is to document present operations in order that they may be examined in detail. This analysis, which is followed by a needs analysis, lays the foundation for the CIM program and for future business planning. It should result in a comprehensive working model of the enterprise which should be presented mainly in graphical form to facilitate the effective summarization of the company's business operations.

Graphical representations of facilities, product flow, information flow, and functional hierarchy are critical to the "As Is" analysis stage of CIM planning because pictorial descriptions of the business operations allow great insight into the company infrastructure. They provide an accurate, detailed overview of the enterprise that members of the company can readily conceptualize for planning purposes.

The ultimate goal of the CIM program is to make the company a more effective competitor by reducing the complexity of operations, eliminating duplication of effort, and minimizing manual collection, transfer, and compilation of information. An "As Is" analysis and the subsequent needs analysis are needed because blindly computerizing existing methods and procedures is ineffective and may even be counterproductive. In most companies, established modes of operation have been developed over time, taking only single functions into consideration and without regard to their place in the overall operation of the business. Consequently, many existing business operations are inherently inefficient and not conducive to integration. The "As Is" analysis pinpoints areas of inefficiency and identifies opportunities for integration. Once the company has been modeled, this planning tool can be maintained with only incremental updating each time a change is incorporated in the business operations.

Once a project team, or task force, has been formed and procedural and reporting guidelines have been established as previously described, the task groups will be prepared to conduct an effective analysis. The size of the task group or groups necessary to perform the "As Is" Analysis will depend on the size of the company and the complexity of its operations. The "As Is" analysis will be a relatively intensive activity. It is proposed that three task force members be dedicated to "As Is" analysis for every hundred employees.

The project leaders selected for this planning activity should be those who will be major contributors to formulating the conceptual CIM plan. In formulating a plan for improving the company's methods, these individuals will require thorough familiarity with the company's present manner of conducting its business. Having been involved in the "As Is" analysis, they will be better prepared to devise methods of simplifying and streamlining the company's operations.

The activities involved in the "As Is" Analysis stage of the CIM planning cycle are:

1. Developing facility and equipment profiles
2. Performing product flow analyses

3. Defining a business function hierarchy

4. Documenting information flow

5. Developing an operational cost model of the business

6. Documenting the employee knowledge base

Except for activity 5, which is dependent on information generated by activity 4, all these activities can be conducted concurrently.

A task group can be formed for each activity. Each group can begin gathering information, which can be exchanged at regular meeting where members of all task groups can exchange ideas for the more effective modeling of the company. For example, early sharing of information compiled by the task group that is establishing the functional hierarchy will benefit the task group that is documenting information flow--and vice versa.

Involvement of end users from various functional disciplines in the "As Is" Analysis benefits the overall information. Providing employees with insight into the operation enables these individuals to envision ways of improving their own functions as they affect others. Having individuals from different disciplines working together on the task group may have the added benefit of breaking down barriers and eliminating rivalries between various functional areas. Benefits of this kind are intangible but nonetheless real.

Developing a Facility and Equipment Profile

The task group assigned the task of developing a facility and equipment profile will be responsible for providing a model of the physical facility and all equipment that is utilized to conduct business operations. The following graphical representations should be prepared.

- A layout of all the company's physical manufacturing, office, and warehousing facilities. This layout should designate all manufacturing equipment and material storage/inventory locations.
- A communications/computer hardware configuration showing the equipment locations as stations should be overlaid on the plant building facilities layout. Communication links and networks should be included on the configuration diagram.
- A breakdown of functional departments by plant

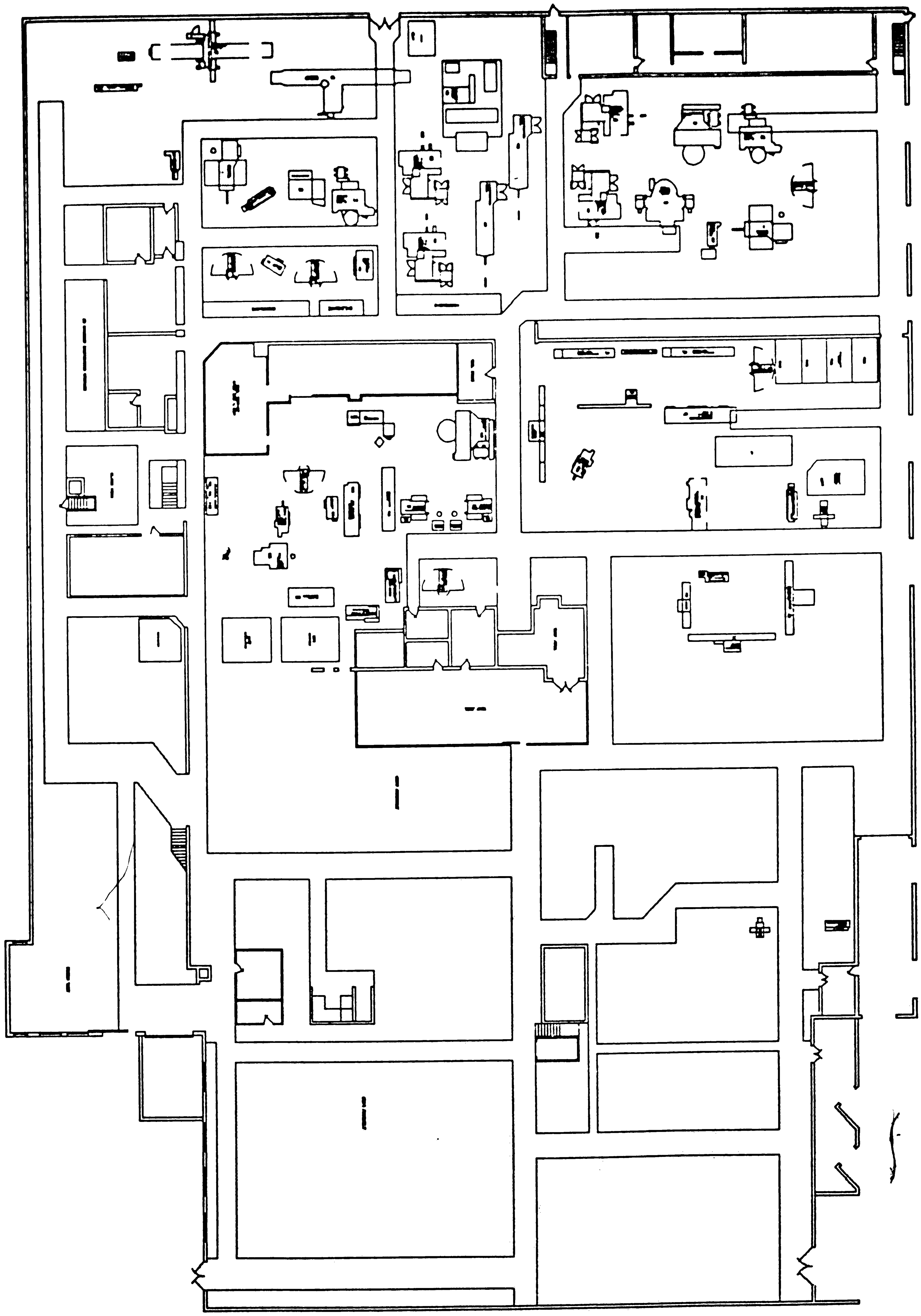
location. If there are multiple plant locations, each plant should be broken down in the same manner.

- An updated version of the engineering systems for all power supply systems, including plant electrical, pneumatic, and hydraulic systems. Inadequate documentation of electrical systems is common in older plants. This can cause major problems in the installation of computer hardware, including electrical spikes from an unidentified, unisolated electrical line.

In addition to graphical diagrams or models of the facilities, it is important to establish the condition of the facility structures the manufacturing equipment. (See Figure 3.) The condition of equipment, systems, and/or processes utilized by the business must also be documented. A profile should be developed for each critical piece of equipment, system, or process, including:

- The entity function.
- The date the entity was purchased.
- The condition of the entity and its maintenance history. If no history is

Figure 3: Facility and Equipment Diagram



available, the practice of maintaining maintenance data for each piece of equipment should be instated in the company's operating policy.

- A performance rating, which can be developed by comparing similar pieces of equipment which perform the same processes or obtaining equipment performance standards from vendors.
- The entity's throughput capacity.
- The degree of utilization of that entity.
- A comparison of the entity implemented in the company to similar currently available entities. In other words, the state of technology with which the company is operating. A list of new features currently available for similar entities might be developed.
- Technologies for that entity that might be expected to become available over the next five years.
- For systems in particular, the level of compatibility between the systems being investigated, other systems utilized in the business, and the latest available systems

should be documented. Separate lists of compatible systems should be prepared for all systems in the company.

The entities that are critical to a company's operations are often uniquely applied or developed by the company that incorporates them. These pieces of equipment, systems, or processes should be considered important sources of competitive advantage. They should be identified and protected from exposure to competitors.

Many considerations must be kept in mind when developing a CIM plan. It is important to cover all areas of consideration when performing the "As Is" analysis. For example, no major new system should be installed in a building that will require major renovation or modification until those modifications have been made. Similarly, no new system should be purchased without a determination of its compatibility with existing systems.

As part of a CIM program, several options will be investigated with respect to implementing new computer-controlled equipment and processes as well as new developments in computer technology. In order to make sound decisions on which areas to modernize or automate, the CIM task force will require a clear understanding of their company's existing facilities and equipment and the associated strengths and weaknesses. It is proposed that the development of facility and equipment profiles will serve to identify the primary tools for the overall business operations.

Performing a Product Flow Analysis

When planning for an overall CIM program, the dynamic operating conditions must be identified in order to present an accurate model of the company. The CIM task force must be able to visualize the complete production facility and its activities. Part of the picture must take the form of a product flow model.

This model should contain functional graphic representations of the manufacturing operation to aid in investigating the flow of key parts or products through the facility. In some instances it will be possible to model all products as they flow through the production facilities, but in many cases this task can become too involved.

Manufacturing companies vary greatly in the number of different parts or products they manufacture. Similarly, there can be considerable variation in the sequence of operations and the combination of those operations within a company's product line. Therefore, it is proposed that the first activity the task group should address is analyzing the type or types of production the company is actually performing. Most manufacturing operations usually can be categorized as mass production, medium lot size or batch production, and small lot production such as a job shop.

The type of production a company is engaged in will determine the direction that the task force should pursue in order to improve manufacturing effectiveness. A commonly used technique for determining a company's product-manufacturing category is called the P-Q, or product-mix, analysis.

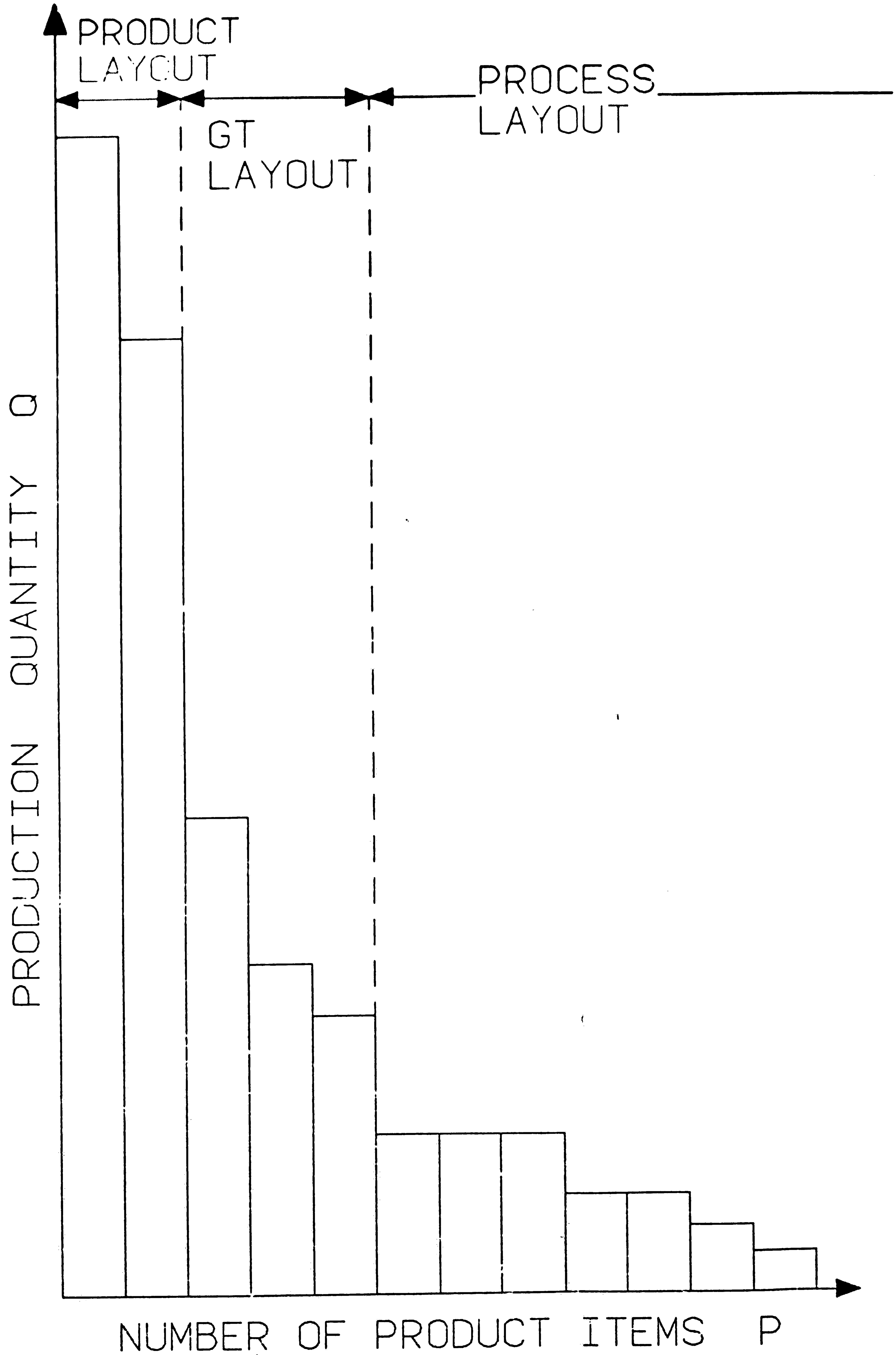
The P-Q Analysis

Among the advantages of the P-Q analysis is that it facilitates the establishment of the optimal plant layout, which should precede the automation of operations of processes. In addition, information regarding the type of production engaged in is required in the needs analysis stage of the CIM cycle.

To determine the type of production the firm is engaged in, it is necessary to calculate the relationship between the number of products P and the production quantity Q. On the basis of the P-Q analysis, a P-Q chart is constructed by arranging products in descending order of quantity produced (Figure 4). This chart is utilized in determining alternative layouts. Possible layouts include:

- Product (production-line) layout. In the case of a large ratio of Q:P, continuous mass production is justified, and production facilities and auxiliary services are located according to the process route for producing the product.
- Group-technology (cellular) layout. In the case of a medium-sized ratio of Q:P in which a wide variety of products can be grouped into group cells, these grouped items are produced as apparent lots, and machines and services are arranged to facilitate this type of production.
- Process (functional) layout. In the case of a low ratio of Q:P, or jobbing of small-lot production, machines and services of like type are located together as work centers in one area of the plant. (Hitomi, 1979)

Figure 4: P-Q Chart
(Hitomi, 1979)



It should be noted that the Q:P ratio utilized to determine the type of production in each individual company is determined by the company's management. Long-term business strategy must be examined to determine the likelihood that the mode of operation will change. It is also necessary to consider the overall trend in manufacturing toward the group-technology type of layout.

A shift toward a group-technology (cellular) layout tends to become desirable or necessary as processes and equipment become more flexible, demand for product variety or customization increases, and inventory carrying costs rise. Similarly, the shift toward a cellular layout occurs as families of parts are established and single machine tools become capable of performing multiple functions.

The P-Q chart serves to identify divisions between products. If one product is produced in large quantities, other products might be manufactured in the same production operation in a process-oriented production style. Once the task group have identified the type or types of production their company is engaged in, the task force can begin to develop an accurate model of the product flow (Figure 5).

Figure 5: Flow Process Chart
(Niebel, 1982)

FLOW PROCESS CHART

SUBJECT CHARTED Shower head face — CHART NO. 1128

DRAWING NO. BA-14782 — PART NO B-14782-2 — CHART OF METHOD Present

CHART BEGINS Bar stock storage — CHARTED BY E. Dunnick

CHART ENDS Assembly Department Storeroom — DATE 9-7 SHEET 1 OF 2

DIST IN FEET	UNIT TIME IN MIN	CHART SYMBOLS	PROCESS DESCRIPTION	DIST. IN FEET	UNIT TIME IN MIN.	CHART SYMBOLS	PROCESS DESCRIPTION
		1	In bar stock storage until requisitioned.		60	6	Waiting press operator.
20	.02	1	Bars loaded on truck upon receipt of requisition.	100		5	To Bliss 74 1/2 press #16 by operator.
600	.05	1	Extruded rod to air saw #72.		.075	6	Pierce 6 holes.
15	.02	2	Bars removed from truck and stored on rack near machine.		120	7	Waiting drill press operator.
	120	1	Waiting for operation to begin.	50		6	To drill press by operator.
	.077	3	Saw slug on air saw.		.334	7	Rough ream and chamfer L. & G. drill press #19.
	30	2	Waiting for move--man.		30	8	Waiting drill press operator.
70	.03	2	Slugs to Nat. Maxi-press #8.	20		7	To Avery drill press #21 by operator.
	15	3	Awaiting forging operation.		.152	8	Drill three 13/64" holes Avery press #21.
	.234	1	Forge (3-man operation) and inspect.		20	9	Awaiting turret lathe operator.
	10	4	Waiting for press operator.	60		8	To turret lathe section by operator.
30		3	To press by operator.		.522	9	Turn stem and face #3 W. & S.
	.061	4	Trim Flash Bliss 74 1/2 press #16.		60	10	Awaiting turret lathe operator.
	30	5	Waiting for pickling operator.	30		9	To adjacent turret lathe operator.
100		4	To pickling tanks by operator.		.648	10	From outside diameter and face back.
	.007	5	Pickle (HCL tank).		15	11	Waiting press operator.

Developing a Model of Product Flow

Flow process charts (see Figure 5) clearly show all transportations of materials, delays, and points of storage, that occur in the course of production, including the distances between functions. These charts are extremely helpful tools in demonstrating how the layout of a plant can be improved to reduce the number and/or duration of these elements. (Niebel, 1982)

The process of charting production flow is relatively straightforward in the case of manufacturing operations that involve a limited number of products or those utilizing a production line or process-oriented type of production. It is more difficult to chart the product flow in batch-oriented or job-shop operations. Even in such cases, however, a company generally specializes in a particular industry or type of service, which usually permits products to be grouped. For cases of this kind, the value of the flow-process charting technique can be realized by the following procedure.

Charting Production Flow in Batch or Job-Shop Operations. First, statistics are collected for principal products or, in the case of a job shop, for parts of similar type that the manufacturing operation produces. A general rule for determining principal products is to account for 75 percent of production time recorded over the preceding three years. These products are then ranked according to the number of production hours. If computer records of production time by product are available, classifying parts according to production time should be simple. If not, the task group should attempt to arrive at as accurate an estimate as possible of which parts are produced in high volume or are most time-consuming to produce.

Second, the routings of the principal parts should be analyzed to identify major part families or product categories. Those parts that have similar routings or process-related features should be grouped into families.

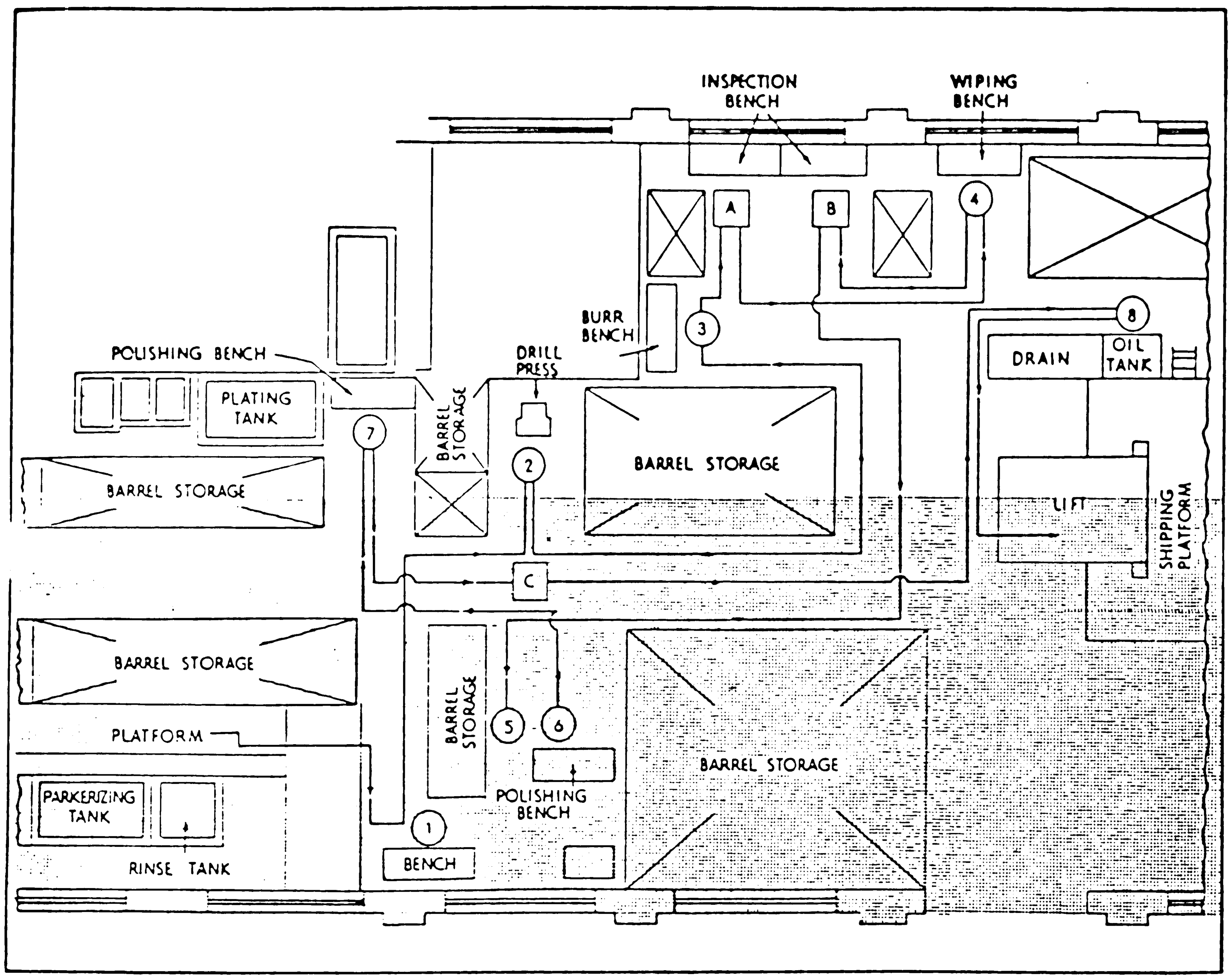
Third, annual production volumes for each principal (high-volume) part should be recorded and the highest-volume product, or primary product, for each category identified. Finally, flow process charts should then be developed for each of the primary products that have been identified.

Development of Flow Diagrams. The next step in product flow modeling is to develop flow diagrams for each of the representative parts or products for all product categories. These diagrams show a schematic plan of the flow of work through the production facility. (See Figure 6.)

Flow diagrams are constructed by taking the existing drawing of the manufacturing facility layout and overlaying flow lines which indicate the movement of material through the plant. These diagrams will be very useful in the needs analysis stage of the CIM planning cycle. For example, if the flow of material is determined to be arbitrary and inefficient, it would be undesirable to plan a material handling system to automate the transportation of materials through the existing layout. (Niebel, 1982) Instead, new, more efficient product flow lines can be overlaid on the facilities and equipment diagram.

Utilizing Input from Production Peronnel. In addition to modeling the facility graphically, the product flow task group should document their observations and utilize the suggestions of individuals who work in the production operation. Equipment operators often have a very good feel for how to improve their immediate operation and other related

Figure 6: Production Flow Diagram
(Niebel, 1982)



aspects of manufacturing. However, they may hesitate to volunteer suggestions. Therefore it is strongly suggested that the task group make a special effort to solicit input from equipment operators and manufacturing personnel.

Dynamic Modeling. The product flow diagrams lead naturally into the process of dynamically modeling the manufacturing conditions. In order to determine the company's overall manufacturing capacities, the typical product flow conditions should be modeled and analyzed. Once the manufacturing operations have been dynamically modeled, feasible alternative configurations can be developed by means of a production-oriented facility model.

Simulation Modeling. A tool for modeling the production activities and accounting for the dynamic changes that take place in everyday manufacturing is a simulation software package. Simulation is a technique involving the use of high level computer languages to model physical conditions. It is appropriate for use in any manufacturing activity where the main objective is to improve the efficiency of existing plants or to optimize the utility of planned new facilities.

Simulation models can be used for design, procedural analysis, and performance assessment. This tool provides managers with the means to evaluate alternatives, both mathematically and visually, and to gauge the impact that planned changes in one area will have on other operations in the business. Simulation packages can generate statistics on operating conditions which depict the outcomes of changed input conditions. By varying the input conditions, managers can statistically predict the effect of different operating conditions such as adding a new piece of equipment at a production bottleneck area or increasing production of a certain part. (Pritsker, 1984)

Recent developments in simulation software packages have brought the capability to do graphical animation as an added feature. Company management could then see the system change as the simulation exercise progresses. This development will allow management to gain an even deeper insight into the manufacturing operations.

As the product flow task group develops a simulation model of the manufacturing operations, there may be some necessity to simplify actual production conditions in order to generate a model of the entire manufacturing operations. This simplification will consist of modeling only the primary products in the case of wide product variety.

The product flow task group will gain valuable insight into the manufacturing operation as they proceed to complete the modeling activities. In addition to generating graphic and computer models of the manufacturing operation, the task group will need to document various characteristics of the product flow and operations.

<u>Documenting Product Flow</u>

It is necessary that certain questions be answered if product flow is to be documented adequately. These questions include the following.

- How is the manufacturing facility laid out? Is it a product layout for mass production, a group-technology of cellular layout for batch of medium-lot manufacturing, a process layout for jobbing/small lot manufacturing, or a combination of these types?

- Is the facility laid out to promote a smooth flow of parts through the production facility? That is, does the production of the majority of parts allow short transportation to the next machine without moving from one extreme of the plant to the other?

- Are there areas where there seem to be bottlenecks in production?
- Are large amounts of work-in-process inventory located throughout the facility and at individual work centers?
- What is the average length of time the primary product materials are present in company facilities? This would include time from the receipt of raw materials until the final product is shipped. This information could be determined through random sampling or by tracking primary products by computer from receiving to shipping.
- For what percentage of the time that primary products are on site are they actually loaded on production equipment? This figure will establish current conditions and will give the manufacturing managers a starting point for setting new goals.
- What are the average product lead times from the creation of the manufacturing order until shipment?

- Are products manufactured to demand or to inventory requirements established by forecasts?
- What is the scrap rate for the entire manufacturing operation, each of the product categories (or families), and each primary product?
- What are the average equipment utilization figures for each major piece of manufacturing equipment?
- What are the capacities of manufacturing equipment?
- What is the overall production capacity of the manufacturing facilities?
- What is the average number of material handling operations performed on the primary products as compared with the number of manufacturing operations? Again, this information could be established by conducting random sampling studies.
- Could existing equipment be replaced by currently available machines or processes that can perform multiple operations required for particular product families or operations that

have been automated to a higher degree is possible with existing equipment?

By documenting existing conditions and establishing an accurate model of the facility and product flow, the CIM planning task force will be in an ideal position to improve the facilities layout to optimize manufacturing effectiveness. As a result the task force will be able to achieve: (Hitomi, 1979)

- o Efficiency of production. Products can be produced in such amounts and at such times required by production demands.
- o Stability of utilization of production facilities. The production capacity and the operative manpower (the number of operators) are well balanced, and the utilization of production facilities is high and stable.
- o Small work-in-process inventories. The smooth work flow results in the minimal work-in-process inventories between work stations.
- o Flexibility and adaptability of production. A wide variety of product types and quantities can be manufactured, adapting to the dynamically changing market. In addition, the

plant possesses the potential for future expansion and modernization.

- Optimal economy of production.

Defining the Functional Hierarchy of the Business

An area related to product flow is the flow of information. Information is generated throughout the manufacture of products. Although the flow of information at times parallels the flow of products, information flow associated directly with production is only a small percentage of the information generated in the course of doing business. Every business function requires information. To determine the flow of information and the information requirements of the entire business operation, the functional hierarchy of the company should be investigated and documented.

Like many complex systems, the functions and activities that take place during the day-to-day operations of a business can best be described in a hierarchical fashion. Business activities must take place in a certain order. To identify this order, each main business function must be broken down into a defined set of subfunctions, and those subfunctions must further be broken down into their respective subdivisions, and so on until the entire business operation has been described.

Company operations consist of repeated cyclings through the hierarchical groupings of functions of which that company's its particular business activities are composed. (Hitomi, 1979) Once the hierarchical structure of the business has been documented, the process of developing more effective modes of operation can begin. The functional breakdown of all business activities will facilitate the accurate description of the company's operating infrastructure. The task group assigned this activity will be required to document all relevant information pertaining to the accomplishment of each functional activity.

To complete the task of documenting the business functional hierarchy the selected task group will have to decide among several available approaches, or they may develop their own approach.

The ICAM Program

The U.S. Air Force, in cooperation with Hughes Aircraft Corporation, has developed an Integrated Computer-Aided Manufacturing program (ICAM) for modeling functional hierarchies. The approach is part of the ICAM Definition Method (IDEF), a modeling methodology whose purpose is to capture the characteristics of a manufacturing operation graphically. (Bravoco, 1985)

The function model, IDEF , describes manufacturing in terms of a hierarchy of functions that are collectively referred to as decisions, actions, and activities. To distinguish between functions, the modeler is required to identify what objects are input to the function, what objects are output from the function, and what objects control the functions and mechanisms (people, tools, etc.)

An IDEF function breakdown is depicted in Figure 7. In Figure 8, the basic breakdown ("decomposition") of manufacturing is portrayed: (1) to plan manufcturing, (2) to provide materials/resources, and (3) to perform manufacturing. Using the IDEF methodology, the decomposed function model can show any level of detail, acting as a "blueprint" description of what is being performed. The diagram is supported by test and glossary. (Young & Mayer, 1984)

CIM task group members may find this type of modeling difficult to use and confusing to follow, however. They may develop their own modeling or

Figure 7: IDEF Function Model
(Bravoco, 1985)

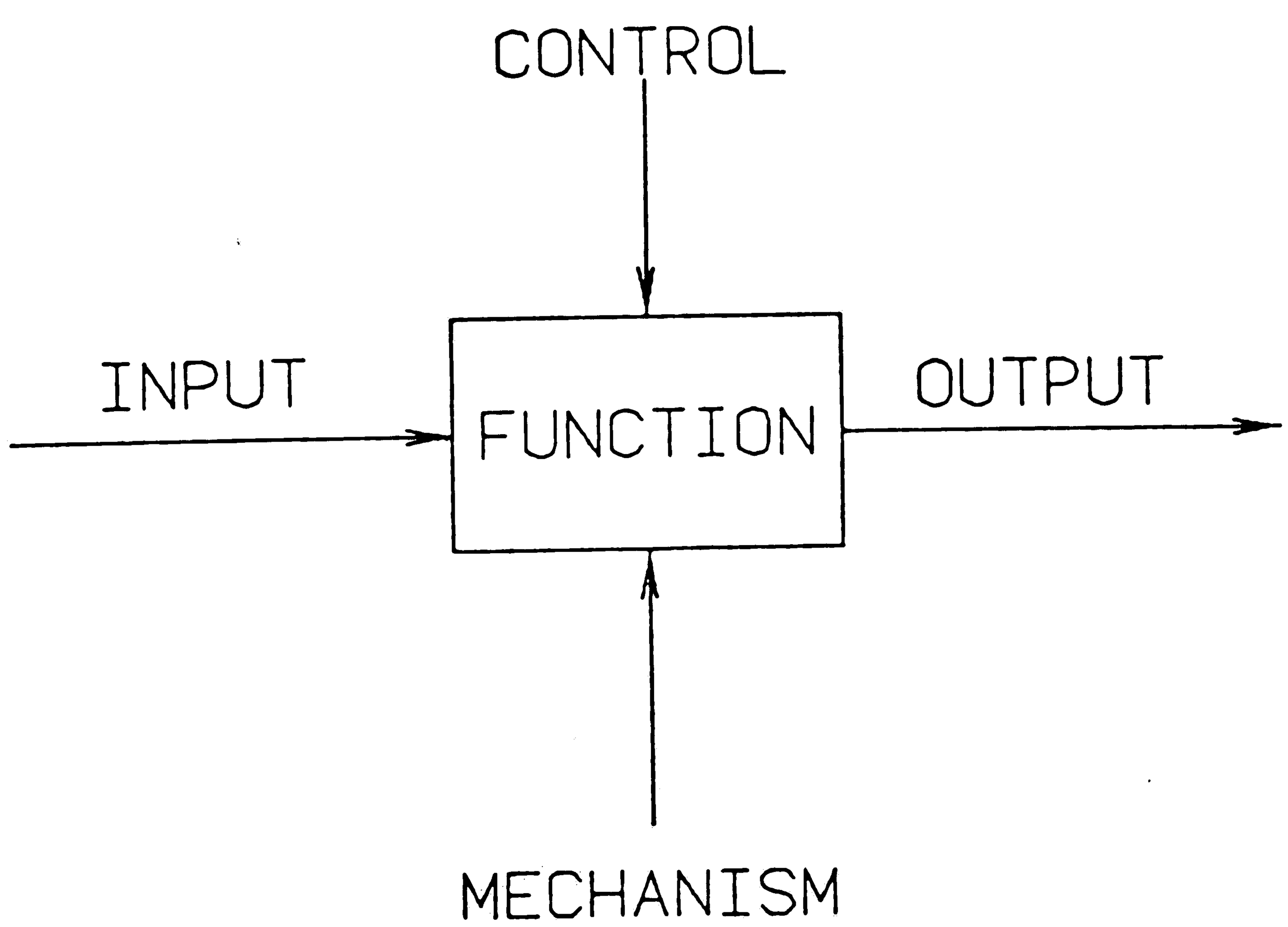
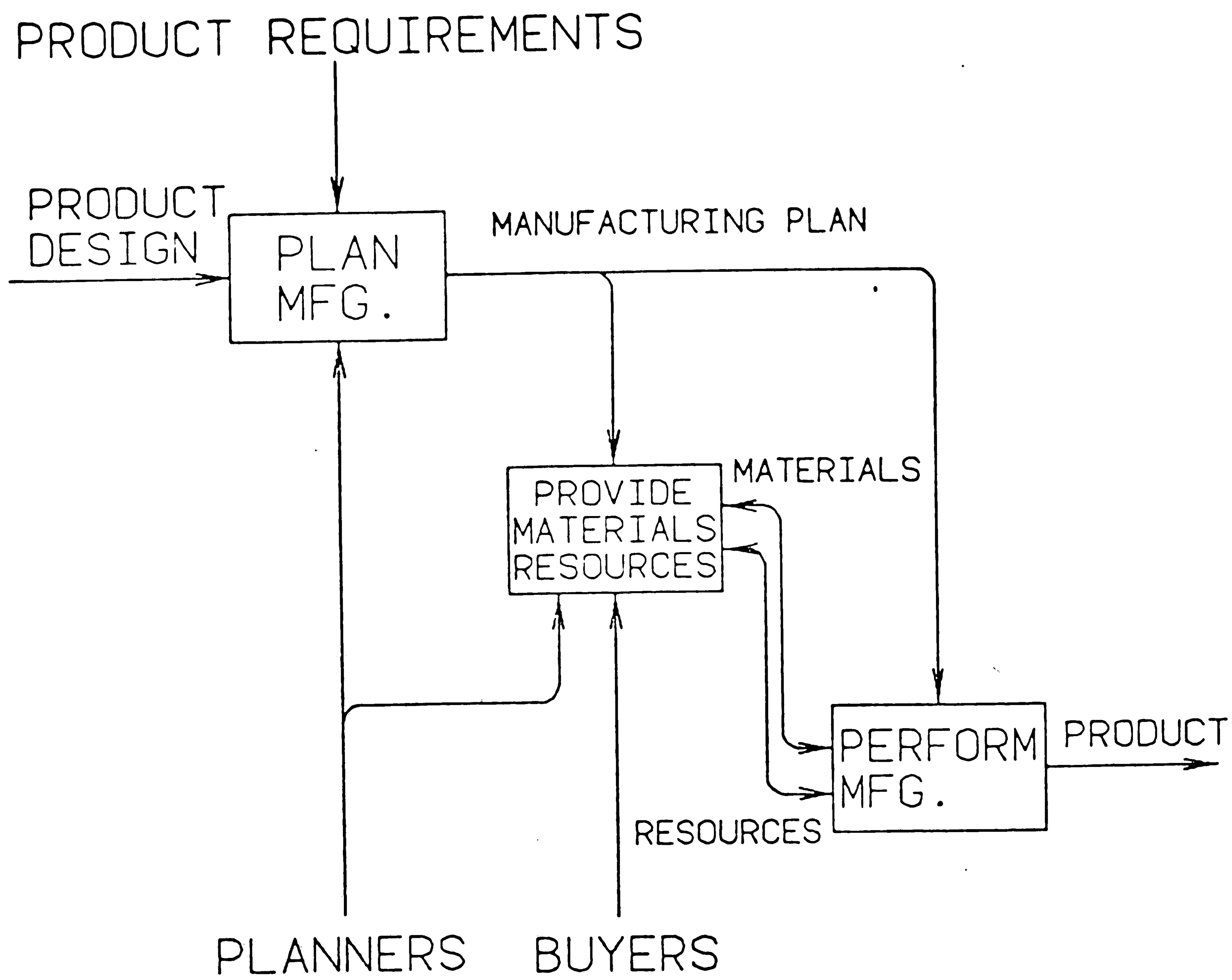


Figure 8: Functional Linkage Model
(Bravoco, 1985)



documentation method in that case. It is important, however, that the activity be completed.

A Suggested Approach

An individualized methodology for defining functional hierarchy may begin with the preparation of an organizational chart that depicts functional descriptions in a hierarchical diagram. The task may proceed in the following steps. A questionnaire like that depicted in Figure 9 may be utilized to solicit information from functional managers.

1. The business is broken down into departments, subdepartments, functions, and subfunctions (all subdivisions of the business functional hierarchy are hereafter referred to collectively as functions)
2. If no organizational chart currently exists, such a chart is created, with every job title and employee holding that position identified.
3. Some form of hierarchical diagram is developed for each level of business function, identifying its relationship to the next higher and next lower level. The company's organizational charts may be utilized, with

Figure 9: Functional Questionnaire

WORKSHEET A

BUSINESS FUNCTION DESCRIPTION

MAIN DEPARTMENT: ______________________ DEPARTMENT DIVISION: ______________________

FUNCTION: ______________________ SUB-FUNCTION: ______________________

PERSONNEL

Name	Job Title	Individual Responsibilities

WORKSHEET B

BUSINESS FUNCTION

Major Responsibilities	Activities Involved	Personnel Responsible

WORKSHEET C

INFORMATION GENERATION

Info. Form & Title	Personnel & Function	Info. Destination (Pers. or Func.)	Info. Handling Tools or Data Generation Equip.

job titles serving as an indicator of business function.

4. A business-function database is created to document the following information for each function:

   a. Functional responsibilities

   b. Job titles of all personnel

   c. Individual job responsibilities

   d. Information requirements broken down by job function

   e. Sources of information utilized in performance of that function, including charts, graphs, reports, files, references

   f. Information generated by the function

   g. Information generated by each job within the function

   h. The destination of all information generated

5. A matrix of information-systems applications and computer-generated reports is then generated, identifying personnel who use those information-systems resources.

6. The critical function of the business are

identified through discussions with department heads.

Having documented the functional hierarchy of the company and its information requirements in the form of a functional model and a functional database, the CIM task group will be able to present senior management with a detailed breakdown of the company's business functions. By means of this breakdown into small, more manageable components, a complex system has been rendered more comprehensible. By establishing connection between people and systems and establishing the inherent functional relationships of the business, the functional model provides a context for building a model of informational relationships, the next stage of the "As Is" analysis.

Information Flow Analysis

Computer integrated manufacturing is based on information. Machine processes can be physically segregated, but information, like a fluid, flows continuously. The flow of information and its analysis is an important thread in understanding the business operations and their interplay. Each business function relies on data and information to perform its activities. Data will be used, accessed, and transformed by many different people. (Elvia, 1985) These data are then compiled to form information, and the information is further combined and condensed as it is funneled up the functional hierarchy of the enterprise to senior management.

At the highest levels of management, information is used to make the strategic decisions crucial to maintaining the company's competitive position. For this reason, it is critical that the information be accurate, appropriate, timely, and presented in the right form for efficient summarization.

In addition to being a medium for control, information is the thread that holds an organization together. (Elvia, 1985) All functions are interconnected to form the working business operation by a network of information transfers. Information not only drives all functions within a business but, more significantly, it drives all aspects of doing business from initial customer-vendor contact to distribution of goods and customer service. It is therefore critical that the CIM planning task force have a clear understanding of the information infrastructure of the enterprise. (Young & Mayer, 1984).

An effective CIM system requires that information be viewed as an enterprise-wide corporate resource encompassing manual and computer storage and processing and that the management of information be based upon design and not happenstance. In order to design an effective business operation with smooth information flow, the task force will require an accurate model of the information flow.

Developing an Information Flow Model

In many ways the information flow analysis will parallel the activities of the product flow analysis. For example, the task group assigned to perform the information flow analysis will develop an information flow model of the entire business organization. The task force or task group will be responsible for tracking the creation, analysis, transmittal, and management of information throughout the business operation. The completed information model, combined with the facility and equipment profiles, the product flow model, and the functional analysis, will provide the CIM planning task force with the mechanism for planning the optimal CIM program for the company.

The information-flow task group can work with the functional analysis task group to identify and model all information-related activities. The information model should follow the natural flow of activities occurring at the company. For example, the normal sequence of activities at a manufacturing-oriented company begins with the customer order, moves from sales to production control, then through manufacturing to storage, and ends with shipping. This main flow of business activities is in turn composed of hundreds of minor activities that support the major activities and others in which the business must participate.

Limitations of Existing Methodologies Several techniques are currently available for modeling information and data relationships, including IBM's Relational Information Model, Honeywell's Data Structure Diagrams, Chen's Entity-Relationship Model, James Martin's Canonical Data Model, Control Data's Information Analysis Technique, DACOM's Info Model-ER, and ICAM's IDEF . (Snodgrass, 1984) The developers of these techniques are striving to establish a information and data modeling discipline that provides a refined information structure for the entire enterprise as a natural result of the system development process.

One example of these techniques is the IDEF technique, which is specifically designed to model information relationships in manufacturing systems. The IDEF Information Modeling Methodology (IDEF) was developed for ICAM by Hughes Aircraft Corporation. The IDEF information model is a dictionary or a structured description supported by a glossary which defines, cross-references, relates, and characterizes information at a desired level of detail necessary to support the manufacturing environment. (Young & Mayer, 1984)

Existing techniques for information modeling have been designed primarily for use in developing information systems, and their modeling activities are therefore structures to assist in software development. Despite their usefulness in developing computer applications, they lack the ability to quickly and simply portray the information infrastructure of an enterprise. Figure 10 depicts production control as modeled through structured techniques. The diagram has several direction arrows, and in order to follow the flow of information it is necessary to page through different diagrams.

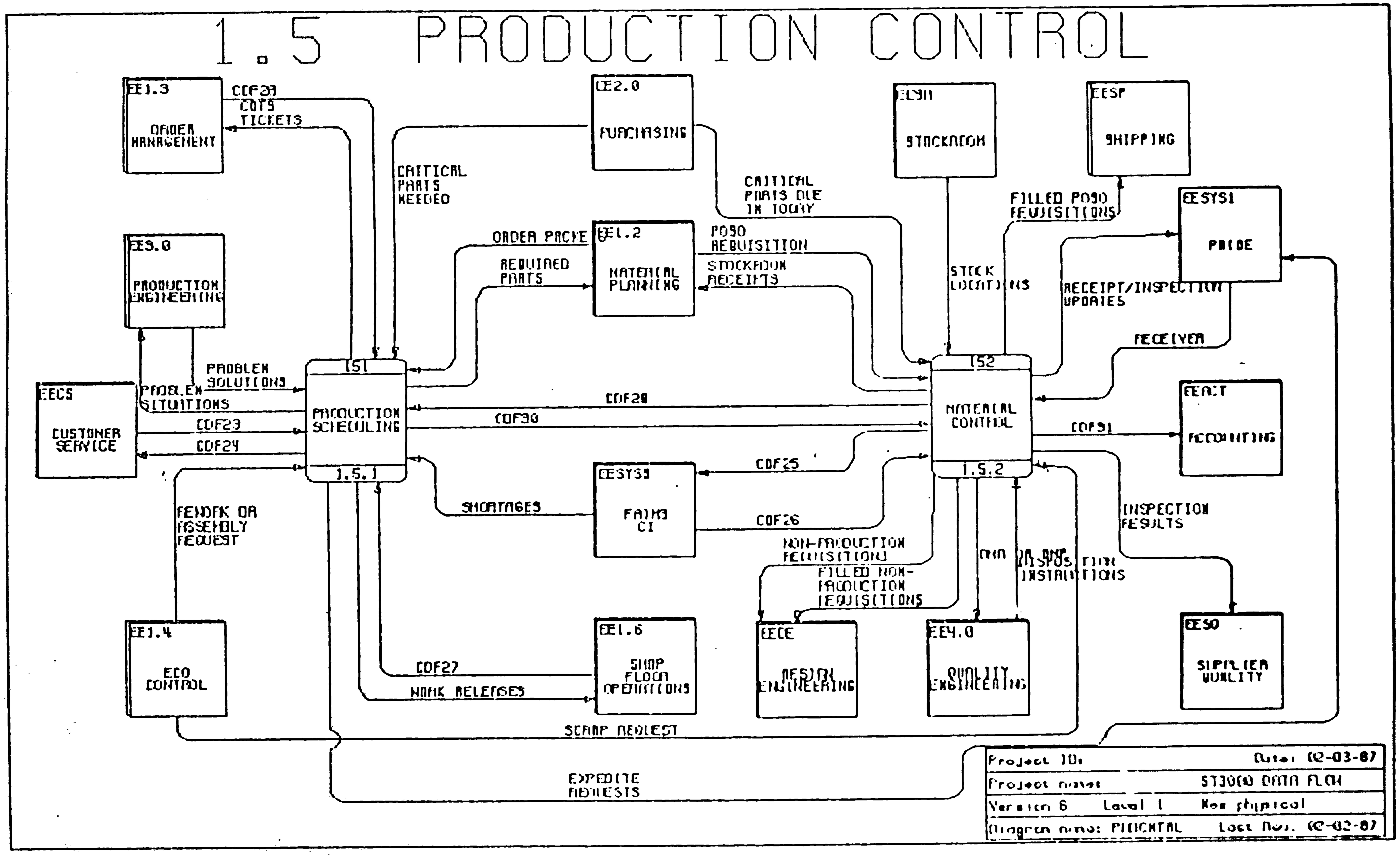
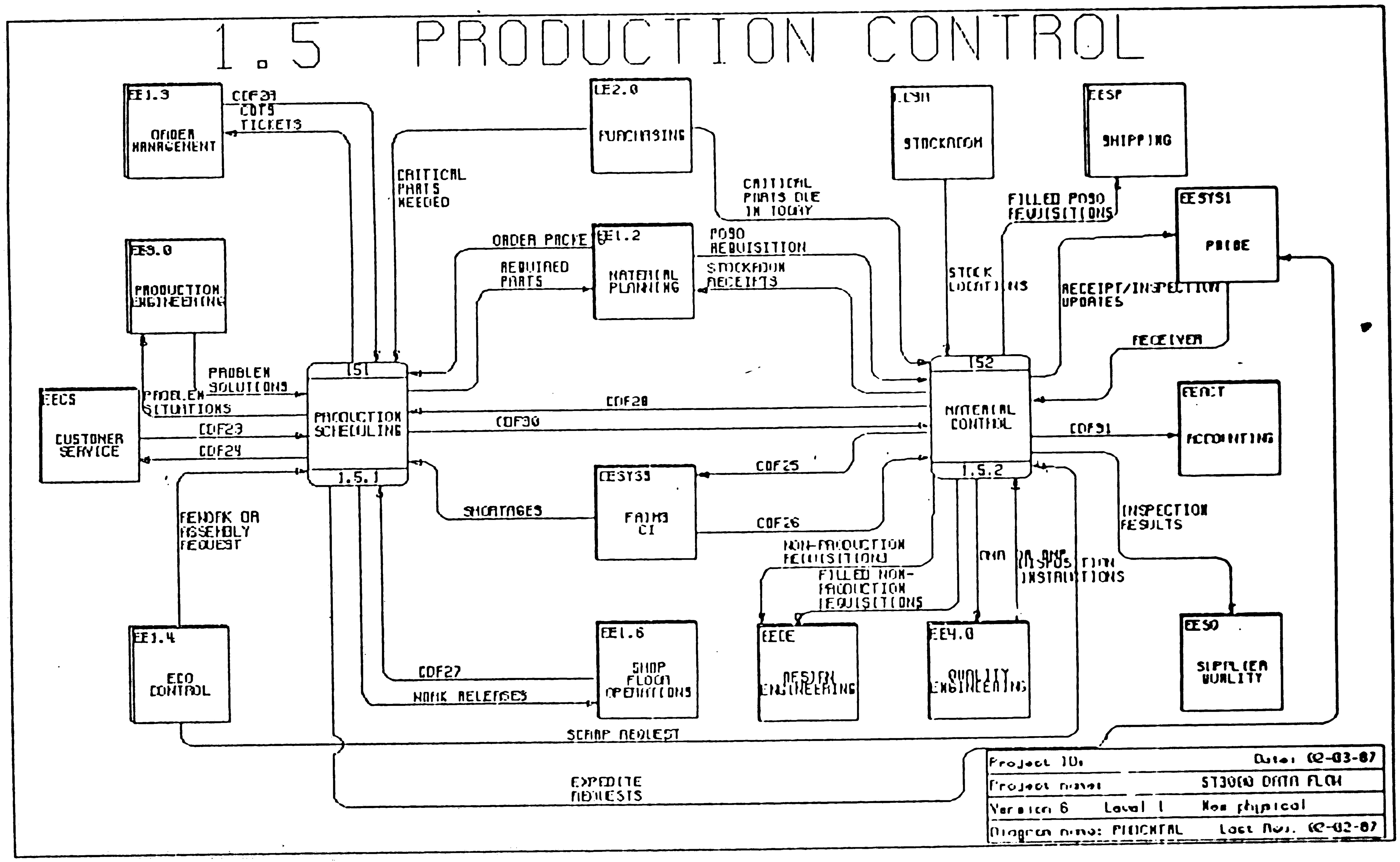


Figure 10 Example of the Structured Information Modeling Technique

Proposed Technique for Modeling Information Flow. An alternative technique for modeling information flow has been developed by this researcher. It is easier to follow than existing techniques and explicitly depicts the flow of information through the various functional groups of an enterprise (Figure 11). This technique derives its basic concepts from two related diagramming techinques: the flow process chart described in product flow analysis section of this paper and the standard programming flow chart. The flow process chart is an industrial engineering technique used for methods analysis. The standard programming flow chart is a diagramming technique used to illustrate the sequence of a computer program. These techniques can be combined to produce an information flow model depicting the sequence of events that transpires during the daily operation of a business.

For purposes of CIM planning, the information flow model may be utilized to plan strategically for more effective dissemination of information. When combined with the functional analysis, this methodology should reflect the basic structure of an organization, its operations, and any inconsistencies between the actual



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information infrastructure of an organization and its intended method of operation. Documenting and modeling an organization's information infrastructure consists of a series of steps.

1. The information analysis task group begins by documenting the flow of basic product-dependent information through the organization. The outcome of this activity will be a diagram depicting the flow of information through the basic functional groups of the company (Figures 12 and 13).

2. The information flow task group should then consult with the functional analysis task group to gain an understanding of the functional relationships within the company, to resolve any discrepancies in naming or categorizing of functions, and to identify additional functional areas that are part of the critical flow of business information. At this point the information flow analysis task force can update the functional flow analysis and review it with key members of management and the CIM planning task force.

3. Having established the information flow between functional groups of the company, the task force can begin detailed analysis and documentation of detail all

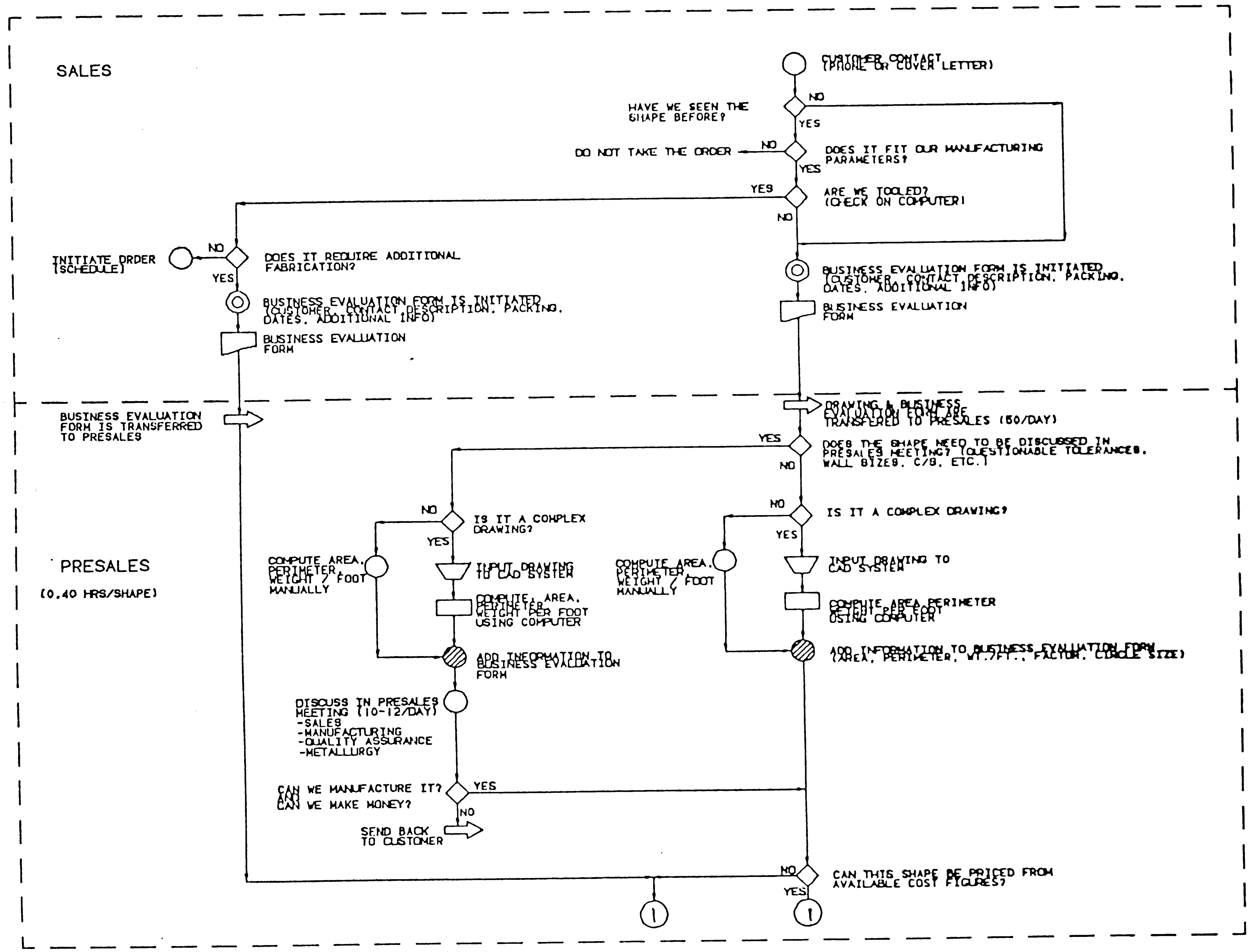
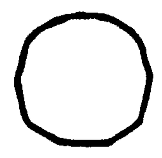
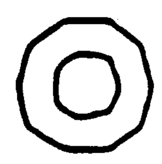
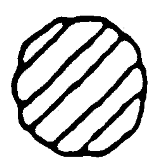


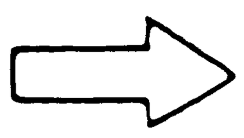
Figure 12: Example of an Information Flow Diagram

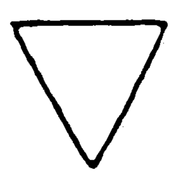
Figure 13: Information Flow Control Key

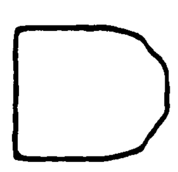
1)  → PAPER OPERATION; SORTING, COMBINING, OR RETRIEVING DOCUMENTS

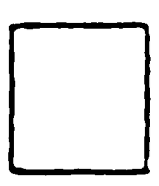
2)  → PAPER OPERATION; CREATE A RECORD OR SET OF DOCUMENTS

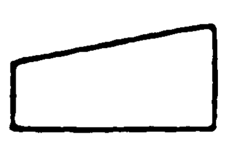
3)  → PAPER OPERATION; ADD INFORMATION TO A DOCUMENT

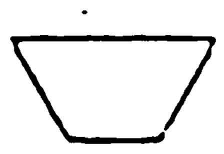
4)  → MANUAL TRANSPORTATION OR TRANSFER OF A DOCUMENT

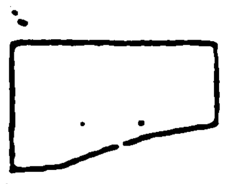
5)  → FILE OR STORE A DOCUMENT

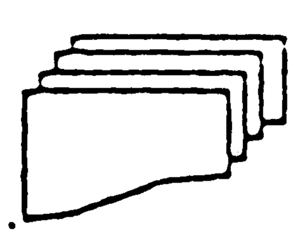
6)  → DELAY IN OPERATIONS OR IN PROCESSING

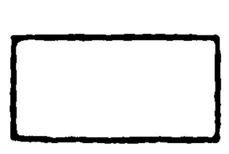
7)  → EXAMINE A PRINTED FORM FOR INFORMATION

8)  → DISPLAY INFORMATION ON A COMPUTER TERMINAL

9)  → INPUT DATA INTO COMPUTER DATA BASE

10)  → DESIGNATES A DOCUMENT

11)  → DESIGNATES A DOCUMENT WITH MULTIPLE COPIES

12)  → INFORMATION IS PROCESSED THROUGH THE COMPUTER SYSTEM

product-related and business-related information activities required to operate the company. This time-consuming activity is carried out in the following manner.

Task group members are assigned to specific related functional groups so that the amount of information-documenting activity is balanced between functional groupings. For example, one task force member may be responsible for documenting sales and order entry, another task force member may be responsible for new-product design, and so on.

The task group member assigned to a particular function will then establish the key personnel in the flow of information through the groups participating in that function. In order to actually document the flow of information, the task group member will have to conduct interviews with each key individual. It is not sufficient to merely interview a functional manager or supervisor. That individual may have a clear understanding of the responsibilities of his or her subordinates, but it is very difficult to comprehend all the information-related activities that take place. Each person who handles the information in any manner should be interviewed. The information derived from these interviews must be accurately documented in the form of a written narrative and an information flow diagramlike that shown in Figure 12.

After the interviews have been completed, the information flow documentation and diagrams should be reviewed in a meeting between the task group member, the task group leader, and the functional area personnel for a final check of accuracy. The individually developed diagrams are then presented to the task group and combined. In this manner the flow of information throughout the enterprise can be modeled for further analysis.

Advantages of Structured Information Modeling

A structured information modeling approach provides organization, clarity, and standardization to a description otherwise require thousands of words of description. With regard to CIM planning, the information flow model is the most critical model to develop. It will serve as the primary tool for the needs analysis and for formulating the conceptual design of the CIM program as discussed in subsequent sections.

The advantage of the information model approach to describing manufacturing is that it provides an essentially invariant structure around which databases and application subsystems can be designed to handle the changing requirements of manufacturing information. Careful study of the information model in conjunction with the static functional hierarchy will allow the CIM planning task force to determine those functions that (1) are redundant and superfluous, (2) have access to unneeded information, (3) are overwhelmed with information, and (4) have insufficient information.

By examining the activity dynamics of the information flow model in conjuction with the functional requirements analysis, the following information about processing activities and the information they require can be obtained:

- The types of information processing required at a function
- The information entities and relationships that must be accessed in order to process the information
- The sensitivity of the information used
- The implications of a processing error

The information-flow modeling techniques described may be utilized to design a business operation in which CIM can be efffectively applied. Without careful determination of the appropriateness and implications of its application, computerization may not only fail to provide significant improvements but may actually contribute additional confusion in information-related activities. Moreover, analysis of information flow often uncovers inconsistencies between the information infrastructure and the intended operation of the business. Only when a detailed understanding of a company's current information infrastructure has been achieved is it possible to plan an optimal structure.

Operational Cost Analysis

In order to evaluate CIM applications, it is first necessary to establish a measure of value or benefit. An evaluation of the costs associated with business activities requires that an operational cost model encompassing the entire enterprise be established.

Traditionally, companies have used a direct labor-based cost accounting system as a basis for capital expenditure justification. (Young & Mayer, 1984) The use of such a system implies that the strongest candidates for project justification are selected on the basis of the anticipated dollar savings in direct labor costs. This method of project selection is inadequate for financial analysis and justification of new CIM technologies. (Young & Mayer, 1984) All costs associated with doing business must be identified and documented in order to effectively prioritize the components of a CIM program

In the past, direct labor represented a major portion of operating cost for manufacturing-oriented companies. Consequently, the accounting procedures in use in most companies clearly define direct labor costs by specific manufacturing function and product (Punwani, 1985) Currently, however, direct labor represents less than 10 percent of total manufacturing costs. (Punwani, 1985)

Accounting procedures currently in use tend to specifically identify direct costs, such as raw material and direct labor. Generally, however, they fail in precisely measuring key indirect costs, such as those associated with carrying inventories, scrap, tooling, computer hardware and software development and information handling. These indirect costs are typically lumped together in large overhead pools. Consequently, no generally applicable methodology exists for evaluating the cost/benefit impact of different technologies on significant cost elements within a business function. (Young & Mayer, 1984)

It is important for the task group assigned to operating cost analysis to identify the major cost contributors to the company's operations and to document the results of their analysis. It is proposed that the resulting cost profile of production and the company's total business operation will highlight primary cost factors.

The Functional Cost Profile

It is proposed that the first step to be undertaken by the task group should be to develop a list of major functions that identifies all significant disciplines within the business. The functional hierarchy that was established earlier will help determine the best method for differentiating the major functional areas. Typically, manufacturing-oriented businesses classify operations as: administration, engineering, finance, general (facilities/human services), information services, manufacturing, and marketing and sales.

The proposed next task is the breakdown of each of these major functional groups into cost categories.

All functional areas except manufacturing should be subdivided into such categories as indirect labor salaries, information handling, energy utilization, facilities and equipment amortization, and maintenance, depending on the nature of the business. Sales and purchasing may also be charged with inventory carrying costs. This task will be greatly facilitated if the existing accounting system is set up to reflect actual costs.

Manufacturing will have many more categories, including (Muir, 1985):

Direct production labor

Energy utilization

Engineering support

Equipment amortization (including tooling

Equipment maintenance

Indirect production-oriented labor

Information handling

Information services

Material utilization (scrap)

Plant and facilities amortization

Plant and facilities maintenance

Product and raw material cost

Support material cost

Work-in-process inventory financing

Although providing the cost-category breakdown is a relatively straightforward operation, identifying all the costs associated with each category may prove more difficult if the existing accounting system has identified these cost categories collectively as overhead. Since decisions regarding the assignment of project areas for CIM applications cannot be appropriately made without a detailed understanding of cost distribution, the task group must carefully examine company records to establish the actual cost breakdown.

<u>Evaluating Information-Handling Costs</u>

Indirect labor activity and the information handling costs associated with both direct and indirect labor may prove especially difficult to establish. It is especially important to identify costs associated with information handling, however, because it is these costs that can be most significantly addressed by CIM technologies. (Young & Mayer, 1984)

A major goal of the CIM program should be to reduce indirect costs. These costs currently are equal to direct manufacturing costs (Young & Mayer, 1984). A major contributor to indirect costs is indirect labor, about 50% of of which consists of "white collar" employees engaged in creating, analyzing, transmitting, and managing information needed to support the business (Schneiderman, 1981) CIM technologies were developed to assist in performing these same activities. Therefore, it is imperative that the activities and associated costs of indirect labor, as well as activities which take place within the entire enterprise, be modeled.

Modeling Operational Costs

The information flow chart that is being constructed by another task group should be invaluable in identifying the operational costs of the business, especially those associated with information handling. The proposed method for modeling operational costs includes these steps:

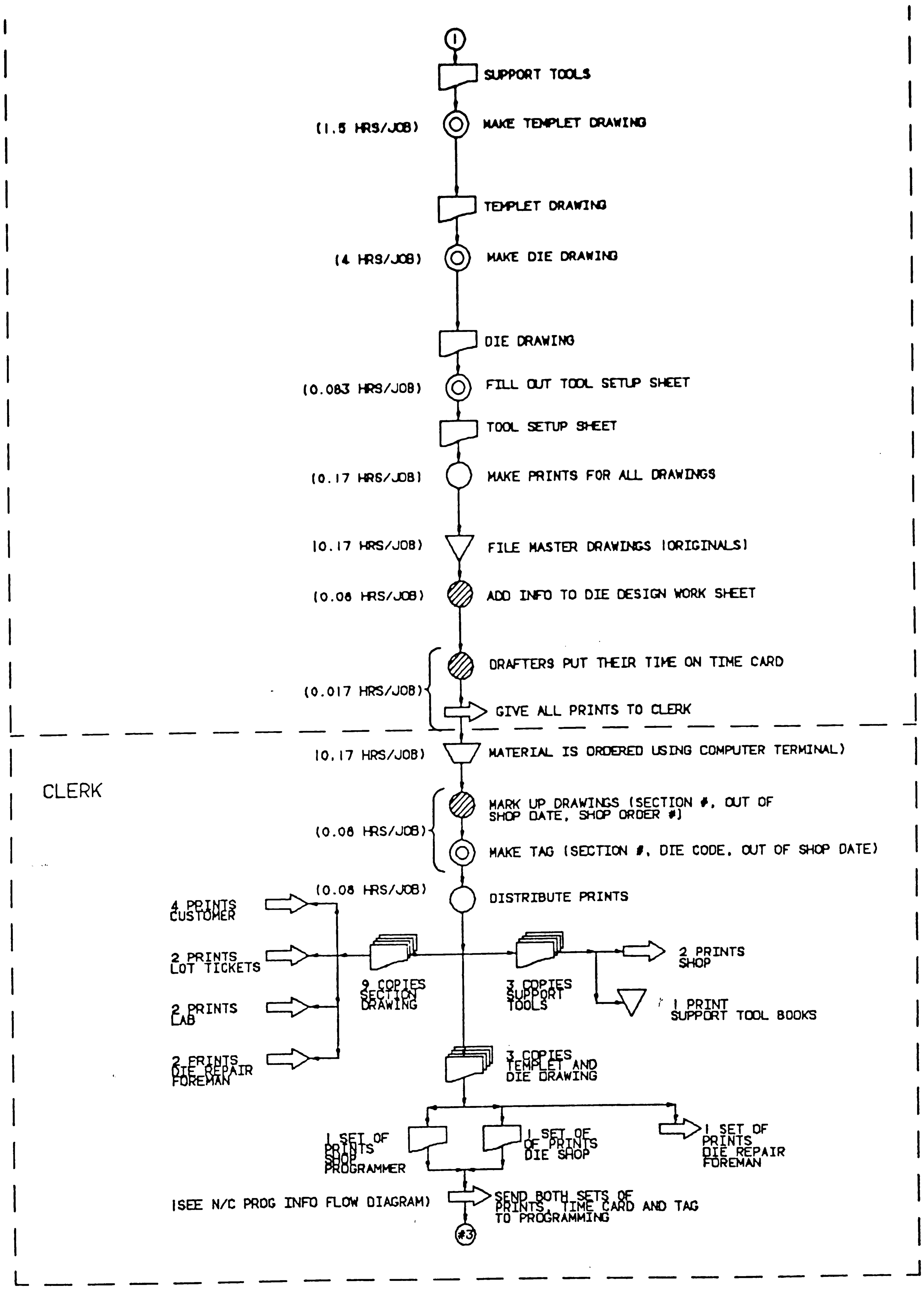
1. The task group is divided into major functional areas of responsibility.
2. Utilizing the information flow chart, task group members document estimated average times for performing each designated activity.
3. Those task-group members responsible for manufacturing combine the information flow chart with the flow process charts completed earlier into a single model that identifies all activities that transpire in manufacturing. (In small-batch manufacturing, the best approach would be to model only the

primary products as separate branches of activity.)

4. At this point, the manufacturing task group should document the times required to perform the activities associated with the average order quantities of each of the primary products. (See Figure 14.)
5. Having established the time for each activity, the task group will be able to utilize wage and salary information in establishing costs for each activity.
6. The information flow chart, the manufacturing activity chart, the times for each activity, and the costs for each activity are combined into a comprehensive model of operational costs.

The resulting operational cost model can be used by the task group to complete their cost breakdown activity. (Punwani, 1985) Using this model, business costs for the current year can be analyzed in a top-down manner throughout the business. Cost elements identified by this CIM planning activity may be different from those used in the company's cost

Figure 14: Example of Operational Time Estimates



accounting system. For example, they will include items such as inventory carrying costs, scrap, rework, energy, and information handling costs, which are not normally tracked and are therefore unavailable for use in a project justification approach.

Using the operational cost model, controllable business costs for each major business function can be systematically broken down into subfunctions. Throughout the process, care should be taken to ensure that each function's cost has been reasonably allocated and that, when combined, the total cost of all functions is equal to the overall controllable business costs for the organization. The accounting department may use the results of this planning activity to restructure some of its procedures.

The final cost breakdown should be presented on spreadsheets and in graphical form in order to provide the steering committee with a comprehensive view of the operational cost breakdowns. This analysis will establish the "As Is" cost baselines for determining the prioritization of improvement projects and will be used to describe the predicted impact of applying CIM technologies to improving enterprise effectiveness. It is therefore important that the assumptions and definitions underlying the cost baseline be explicitly stated and documented during this task. (Muir, 1983)

By studying the cost breakdowns and operational cost model of the company, the CIM planning steering committee can become familiar with all the pertinent details related to the direct and indirect cost of the business operation so that they can be analyzed for improvement.

Documenting the Employee Knowledge Base

Employees are the key resources of any business enterprise. Without the personnel who participate in and drive the business operations, the company would be worth no more than the salvage value of its assets. Often, key employees are following procedures that they have developed after years of experience. Even if formal systems and procedures have been instituted in an effort to standardize activities and impart order to business operations, it is often the case that an informal system actually remains operative and vital. (Young & Mayer, 1984)

It is necessary for the information flow model to address this problem by identifying all informal as well as formal activities that occur in the performance of business functions. Furthermore, completion of the "As Is" analysis requires that the relevant individuals and the specific knowledge that they posses and exercise in order to maintain business activities be documented. (Allen, 1976)

Employee Knowledge As A Competitive Advantage

The knowledge and expertise of employees frequently constitutes a competitive advantage. For example, a company that utilizes a unique process developed within in the company will have two objectives in regard to employees' knowledge of that process: (1) to prevent competitors from acquiring the information and (2) to facilitate continued operation if the individuals who control that process leave the company. Achieving these objectives requires that senior management company assess the vulnerability of its current operations to intentional or accidental leakage of information and to loss of information through the departure of employees possessing it. Once points of vulnerability are identified, management can institute policies to reduce these risks. It is important that this problem be addressed before new CIM technologies are implemented. (Savage, 1985)

Technological knowledge, or "know-how," is an intangible component of a business. It becomes embodied in people in the form of skills and techniques and in industrial plants in the form of operating principles. (Allen, 1976) The value that these individual represent to the company's overall operations must be assessed. To reduce the potential impact of employee departure, unique knowledge must be identified and captured in a form that permits its transmission to new personnel.

Documenting Employee Expertise

In many companies that have been in operation for several decades, individual expertise has been transmitted directly, orally and by example, between those who move on and those who assume their responsibilities. When such a job exchange occurs, however, a large amount of functional knowledge is lost, and the process of learning through mistakes is continually repeated. (Allen, 1976)

Identifying, codifying, and storing the expertise gained by key individuals not only benefits those directly associated with that function but also benefits the overall efficiency of the business. However, it is often the case that key individuals, whether they are direct laborers or professional knowledge workers, keep their job procedures "in their heads" and cannot readily explain exactly how they perform their tasks. It will therefore be the responsibility of the task group to identify these individuals and document the strategic essence of their knowledge base.

The first activity will be to interview department, subdepartment, and functional managers and supervisors to identify those individuals who possess unique and/or critical knowledge of business operations. Once these individuals have been identified, a review of the information flow chart and individualized profiles should be performed.

The task group should enhance the detail of the information flow chart for the key individuals' profiles by adding more details on decision rules and informal procedures. At the very least, this documentation will assist those employees who will eventually take over the same position. More important, this activity will assist in developing a more complete formal system for that function or in providing the groundwork for expert systems development, if such a direction is selected by the CIM planning task force.

In addition, the task group should identify from the group of key individuals those most likely to leave the company. Indicators such as those individuals who are approaching retirement age or those individuals who are highly marketable in similar industries, will help identify those employees who are most likely to leave. These individuals should begin training backup employees to perform their duties in the event of their temporary absence or permanent departure. (Allen, 1976)

Information Management and Communications

A final consideration pertains to information management and communications. A major consideration for CIM planning is the issue of providing top management with accurate, pertinent, and timely information. (Young & Mayer, 1984) By identifying key knowledge workers and a providing a detailed account of their activities, it will be possible to plan information and communication systems to provide key information to the strategic decision-makers. The key knowledge workers can become more accessible and interactive with the managers who need their information through the utilization of new CIM technologies. (Savage, 1985) As a result of documenting the employee knowledge base, managers at all levels will be able to ask more directed questions of their critical employees because they will be better informed themselves, which in turn will generate a more effective approach to business management.

NEEDS ANALYSIS

Once the "As Is" analysis has documented and modeled the current operation of the enterprise, major problem areas and needs can be identified and new methods of operation investigated. In the needs analysis stage of CIM planning, the business functions of the company are analyzed to determine where technology could be employed most effectively to achieve the business goals formulated in the project organization stage. First, however, the strategic business goals must be further refined and incorporated into a grand strategy. This will provide senior management and the CIM steering committee with the direction necessary to plan an optimal CIM program to improve the strategic effectiveness of the company as a whole. (Punwani, 1985 0

The phases of the needs analysis consist of (1) a market analysis, (2) identification of functional improvement areas, (3) identification of requirements for functional improvement, (3) assessment of potential applications for CIM technologies, and (4) determination of the functional improvement potential of CIM technologies.

The Market Analysis

The market analysis is utilized for detailed adjustment of the company's previously formulated strategic goals to accommodate market conditions and to break down these goals into tactical objectives for each functional component of the business. The grand strategy of the business must be analyzed for its consistency and appropriateness to the daily bases of competition by which the company is measured in the marketplace. It can then be modified accordingly. In brief, the market analysis specifically addresses competitive issues in relation to CIM planning.

Selecting an Interdisciplinary Task Group

The first step in defining the company's operational needs is to form a CIM task group to conduct an in-depth market analysis. Obviously, marketing personnel should be included in the task group, but representatives from the manufacturing, engineering, and finance departments are equally important. By exposing other disciplines within the company to marketing requirements, a more informed workforce is obtained and interdepartmental barriers--for example, between marketing and manufacturing--may be reduced.

Once the task group has been formed, its major tasks in identifying the most effective grand strategy for an individual company will be (1) the situation audit, (2) the competitive analysis, and (3) the comparative analysis. The results of these analyses can then be applied by senior management to the refinement of the company's grand strategy.

The Situation Audit

A detailed analysis of the firm's present market situation is conducted to organize and display the factors that are critical to strategic planning, management, and control. The situation audit is not intended as an explicit analysis of each of these factors but rather as an overall organization of facts compiled in the manner proposed below. (Allen, 1976)

Assessment of the External Environment/ Reassessment of the Strategic Plan. The company's high-level goals, objectives, missions, and social responsibilities are reviewed with respect to external conditions such as the general state of the economy, the economic state of the company's particular industry, and government legislation and regulation.

Identification of Organizational Considerations. Areas to be investigated include organizational considerations such as organization structure, power distribution, internal politics, leadership, group and peer structures, and organizational climate. (Allen, 1976)

Assessment of Internal Environment/Examination of Strategic Control. Employee attitude, operational control, technology utilization, product life cycles, business performance, and rewards and incentives are investigated.

Assessment of Resource Requirements. Financial resources, productive capacity, human resources, expertise, and research and development facilities are identified.

Development of a Company Profile. Weaknesses, opportunities, threats to the company, and company strengths are identified.

Assessment of Company Vulnerability. This involves identification of critical support elements, threats that could affect those elements, consequences of such threats, the probability of a threat's materializing, and possible company counteractions.

Development of a Product Portfolio. It is necessary to identify specific marketing strategies, product mix, product potential, market attractiveness by product, profitability by product, general groupings of products as sold (complementary product lines), and production capabilities by product. (Diaz, 1986)

Development of a Customer Portfolio. Customers must be identified by business type, geographical location, product lines purchased, volume per product line, product line volume per geographical area, market trends in sales regions, and vendor characteristics desired. (Allen, 1976)

During the early stages of conducting a situation audit, the approach should be a broad one, providing a basis for determining which areas require more detailed analysis. Thus, the situation audit is primarily concerned with organizing and ranking facts about the organization and its environment. This audit provides a framework for identifying the major forces that affect strategy and developing an understanding of their interrelationships.

By analyzing these interrelationships, the company is in a better position to match its distinctive competencies with external opportunities and to ward off threats by avoiding, correcting, or compensating for existing weaknesses. As part of this effort, excutives may be requested to "play devil's advocate" to their own strategy or plan. This process will help identify the foundations on which the firm depends for survival, the factors that threaten it, and its ability to respond to those threats. (Allen, 1976)

The Competitive Analysis

This step in the market analysis identifies the competitive forces the company faces in the marketplace, thereby leading to a business strategy and CIM program that address those forces. A common approach to competitive analysis is to focus on magnitude of information and ease of access, collecting all available information regarding competitors. The sheer mass of the information creates problems in relating the information to decision making. (MacAvoy, 1983) It is important that the task group assigned to the market analysis obtain specific, accurate information and then organize and summarize that information more maximum strategic usefulness.

The competitive analysis can be broken down into six major tasks: (1) identifying the firm's major competitors, (2) gathering imformation on the identified firms, (3) developing competitor profiles, (4) rating competitors, (5) constructing a competitor/competitive factor matrix, and (6) ranking the competing companies according to their competitive position in the market.

Identifying Major Competitors. The sales force and marketing managers should be able to identify the firm's strongest competitors. For large corporations, the divisional competitors should be limited to approximately thirty to enable the task group to perform a thorough analysis. Information gathered in regard to these companies should include:

- Financial status
- Return on equity
- Sales volume
- Research and development investment
- Development of substitute materials
- Size (number of employees)
- Market share for each of the markets in which the firm competes with the firm doing the analysis
- Product lines
- Technologies utilized in sales, engineering, manufacturing, etc.

- Senior management orientation (i.e., legal, financial, engineering)
- Geographical locations and activities performed at those locations (i.e., sales offices, warehousing/distribution, or manufacturing)

The information can be obtained by (1) performing a literature search encompassing trade publications, association publications, newspaper archives in the competitors' localities, financial publications, and any related industry periodicals, and (2) performing a series of surveys utilizing questionnaires distributed to internal operations employees and sales personnel. Questionnaires may also be distributed to customers, or they may be interviewed informally to ascertain the factors they consider most important in rating customer service.

Developing Competitor Profiles and Ratings. The information generated by the foregoing activities should be organized into a profile for each competitor and the competitors then rated on each of the competitive factors identified by the task group (+10 equaling the strongest possible position and -10 the weakest). Proposed factors for rating include:

- Quality as perceived by customers
- Customer service
- Market responsiveness
- Manufacturing capability
- Return on equity
- Sales volume
- Share of relevant markets
- Potential rate of growth
- Potential for entry into new markets in which the present company competes
- Intensity of rivalry
- Potential for developing substitute materials the will displace the present company's products
- Capability of providing complementary products and services for base competing products
- Reputation for innovation
- Management capability (Allen, 1976)

The relative importance of the chosen factors in the relevant markets is then weighted.

Constructing a Competitor/Competitive Factor Matrix. A matrix is constructed.

For each competing company, the rating

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(+10 to -10) for each factor is multiplied by the competitive weight assigned to that factor and the product placed in a cell. Each company's relative degree of competitiveness can be ascertained by totaling the row or column of the matrix representing the competitor's weighted position. The resulting rankings should then be compared with the companies' actual market position to ascertain whether they reflect actual market conditions. Reassessment of the factor weights may be necessary. (Duncan, 1985)

Completion of this phase of the market analysis should provide a clear and accurate understanding of the status of competitors in the marketplace and the relative importance of each factor contributing to market dominance. The business strategy can then be refined to consider these influences.

The Comparative Analysis

The next major step is to evaluate the company's own performance with respect to the identified competitive factors and to compare that performance with that of its competitors. The accuracy of the results depend in large part on the thoroughness of the competitor analysis. (Allen, 1976) The procedures to be followed parallel those employed in the competitor analysis, except that they are applied to the company itself. Once this procedure has been completed, senior management will be in a position to accurately assess the company's competitive position and develop plans for improvement. Factors to be considered include:

- The comparative ease of attaining improvements in various areas
- Potential for competitive differentiation
- Issues relevant to perceived customer service levels
- Factors that limit perceived quality
- Factors that limit market responsiveness
- The degree of improvement associated with particular sources of competitive advantage that can be expected from a set unit of investment
- Possible shifts in ~~the~~ associated value of identified sources of competitive advantage (MacAvoy, 1983)

It is important to track comparative advantages and the position of competitors. For example, in the early 1960s, Iowa Beef Packers, Inc., began to ship from points closer to the source of their product. The return on equity of this company increased from 13.6 percent in 1971 to 16.3 percent in 1981. The competing companies were not able to respond appropriately. (McAvoy, 1983)

Conversely, when discontinuities do occur in the marketplace, recognition of their existence is prerequisite to corrective action. (MacAvoy, 1983) Assigning a rank order to the factors that limit or control associated costs and/or performance, and comparing the company's performance to that of the competition at each level, it is possible to develop a well-planned business strategy. [B-3]

Refinement of the Strategy

At this point the preliminary strategic plan formulated during the earlier phases of CIM planning can be reevaluated and refined to reflect the insights gained through the market analysis. Each strategic goal must be examined and, if necessary, revised and/or reprioritized. The redefined goals, once authorized by senior management, can be used to formalize a final grand strategy, which must then be broken down into substrategies and objectives for each area of the business and each business function. (Diaz, 1986)

For example, an overall strategic goal might be the improvement of customer service. A variety of substrategies might be employed in pursuit of this goal: providing just-in-time deliveries, providing better information on the status of customer orders, increasing the percentage of on-time deliveries, and so on. Each of these objectives will in turn require that specific tactical objectives be met throughout the enterprise.

The next step requires that the CIM planning committee formulate a hierarchical set of tactical objectives for accomplishment of the grand strategy. These tactical objectives must be clearly defined, precise, and measurable, and time limits must be set for attaining them. (Diaz, 1986) This formulation will constitute, first, problem conceptualization and, finally, development of a CIM master plan.

Identification of Functional Improvement Areas

In order to identify the functional areas requiring improvement, a CIM planning task group should identify the critical success factors (CSFs) of the business. This task is accomplished by (1) identifying the critical factors for control and smooth operation of the business and (2) combining these with the major competitive factors identified in the market analysis. Once the CSFs have been identified, the relevant activities are the functional level can be identified.

This task will assist senior management in pinpointing the precise areas to be examined for potential improvement (1) through changes in procedure and (2) possibly through application of CIM technologies. It is important to remember that omputerized automation is not always the best or the most cost-effective solution. (Diaz, 1986)

By utilizing the business functional hierarchy and the operational model developed during the "As Is" analysis, the task group should be able to determine the required tools within the context of the specific industry and the specific company being evaluated. The proposed steps of this investigation are (1) to establish the major CSFs, and (2) to break down each CSF into supportive functions and subsequently into the related functional activities that compose these supportive functions.

Establishing Major CSFs

The major CSFs of any enterprise are that limited number of activities in which "things must go right" for the continued function of the business. In other words, these factors or elements are the foundations upon which the firm depends for its continued existence. (Elvia, 1985)

To differentiate the most important CSFs, managers of each department may be asked to list the competitive and operational success factors for that department. Senior managers may then establish the five most important CSFs in each category.

Identifying the Most Important Operational CSFs. Management may start by asking: What supportive elements, if suddenly taken away, will have the greatest impact on the business? In most manufacturing-oriented companies, the critical success factors involve: sales and marketing, forecasting, financial control, manufacturing efficiency, materials planning, materials procurement, plant scheduling, information services, engineering, human resources management, and distribution. (Elvia, 1985) Senior management must identify which of these areas are most crucial to the operation of the business.

Identifying the Most Important Competitive CSFs. During the market analysis, competitive factors were ranked in order of important. Senior management should verify this ranking and authorize it.

Assigning a Hierarchy of CSFs. The identified factors must now be ranked in order of importance. Each senior manager is asked to assign points to represent the relative importance (from 1 to 10) of each major CSF. The task group can total these ratings and divide by the number of senior managers participating to obtain a mean score for each factor. The factors can then be ranked accordingly.

The Functional Breakdown

At this point, each of the ten identified CSFs must be broken down into its supportive functions and subsequently into the related functional activities that compose those functions. The method used for operational CSFs is different from that utilized for competitive CSFs.

Operational CSF Breakdown. In performing this task, the CIM planning task group will rely heavily on the business functional hierarchy and the operational model. Each CSF must be located on the operational model, and all its main contributor functions must be identified. The operational model and the functional hierarchy will be helpful in further breaking down the main supportive functions into their major contributing activities. These findings should be reviewed with functional-area personnel. Areas for improvement can then be identified.

Competitive CSF Breakdown. The breakdown of competitive CSFs will be based on the tactical objectives for achievement of strategic goals determined during the market analysis. However, the help of the steering committee should be solicited to determine which functions are responsible for achieving the tactical objectives. The operational model and functional hierarchy will then be utilized to identify Key activities for development.

Priortizing Support Functions

Support functions must be ranked in order of their potential for positively affecting the CSFs. Each functional group identified in the "top-down" analysis should be compared with current company and/or industry strandards to determine how efficiently or effectively it is being executed. (Muir, 1985) The standard of measurement will be determined by the inherent requirements of the associated CSF. Questions to be considered include:

- **Does the functional area meet its objectives relative to the CSF?**
- What functions should be improved in order to enhance the CSF effectively?
- What functional areas are deficient in performance in relation to the CSF?

The notes compiled by the task group that performed the "As Is" analysis should also be consulted to identify inefficiencies.

The Functional Matrix. It is proposed that a matrix be constructed with the functional areas lining one axis and the ten critical success factors lining the other. Each cell designated by a functional area and a CSF will contain two numbers: (1) a rating, from 1 to 10, of the functional areas performance in attaining the CSF, with 10 signifying highest potential for improvement, and (2) the importance rating previously assigned to that function. The performance rating will necessrily be empirical, owing to the nature of this task. Once the matrix has been filled in, the product of the performance rating times the importance factor pertaining to the functional area can be totaled to determine the

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priority for that function, with the highest number receiving highest priority. The functional groups with the highest potential for improvement will thereby be identified.

Identifying Deficiencies

Within the support functions that have been assigned high priorities, deficient supporting functions must be identified. By examining the functional/CSF matrix and understanding why certain supporting functions do not perform to their potential, The task group will be able to highlight deficiencies or opportunities in each of the functional areas. These deficiencies or opportunities should be associated with the composite activities within each functional area. This step enables the task group to quantify problems, diagnose their causes, and identify the needs associated with each of the high-prioroity support functions. (Muir, 1985)

The foregoing steps break down the CSFs into a highly detailed series of events so that all aspects involved are understood and singled out for improvement.

Defining Requirements for Functional Improvement

At this point the task group will define the requirements that will fulfill the needs identified in the functional breakdown. This means that the group will develop methods of compensating for deficiencies and taking advantage of opportunities revealed by the preceding analyses.

In every CIM planning cycle, it is necessary to determine a set of requirements which must be satisfied: What information is needed? How accurate must the information be? What considerations of timing or logistics are involved? What process or procedural developments are needed?--and so forth. From the answers to these and similar questions, generalized definitions for required changes must be formulated. (Stern, 1985)

It is proposed that the needs analysis task group approach this undertaking by utilizing the information developed in the functional analysis previously described. The final objective or objectives pertaining to the CSFs for each functional area must be kept in mind. In some instances, simply identifying the nature of the problem will enable the task group to examine the associated deficiencies and prescribe specific improvements.

For example, suppose that reducing manufacturing costs has been identified as a major CSF, and improving quality control is one objective identified as addressing that area. The company has a functional area entitled quality control. One activity in this area identified as important is to obtain production information on quality and to compile this information weekly. Under the current mode of operation, information about main production processes is being collected, but not all the operations critical to product quality are being monitored. The requirement therefore is to collect information about all activities that affect product quality.

In some situations, requirements are less obvious. Sometimes it may be advantageous to interview the personnel actually performing the activity. The task group will need first to identify the appropriate employees, then to interview them effectively, and last to compile and then intepret the resulting information.

Future as well as current requirements should be considered in investigating functional areas. In addition, it will be necessary to develop a method for quantifying improvements related to any changes. The task committee should define benchmarks for this purpose.

Assessing the Application of CIM Technologies

Once requirements have been defined and prioritized in accordance with the company's strategic goals, it will be necessary to conduct a technology assessment study to evaluate perceived ability of various CIM technologies and procedural changes to meet the functional requirements. A technology assessment involves (1) technology scanning, (2) technology evaluation, and (3) testing for compatibility.

Technology Scanning

To assess what CIM technologies are available, it will be necessary to gather information from a variety of sources. First, the CIM technologies currently used by the company can be ascertained by a simple company audit. Second, the technology used by competitors was identified in the course of the market analysis. Third, a list of available, proven technologies should be compiled by examining the literature and by sending the CIM planning task group assigned to this task to technology conferences, seminars, and expositions where equipment of this kind is demonstrated.

Last, new technologies currently under development should be identified. To accomplish this activity, the task group should solicit information from functional managers, who are likely to be knowledgeable about existing and upcoming technologies pertinent to their specific functions. Alternatively, consultants specializing in the relevant industry may be retained. (Allen, 1976)

It should be noted that the assembling of a database of information regarding CIM technologies should be an ongoing activity. The information should be reviewed regularly to facilitate decisions concerning the competitive advantages of new developments.

Technology Evaluation

The technologies judged to have a direct effect on the CSF supportive functions should be evaluated to determine their capabilities and their state of development. Technological specialists inside or outside the firm may be utilizaed for this process. Two basic questions must be answered: (1) What can the current technologies provide for this company? and (2) Have these technologies been proven in industry.

Personnel from each of the identified CSF support functions should be enlisted for this evaluation. The steps include:

1. Establishing potential technology applications. The information gathered during the "As Is" and needs analyses will permit functional personnel and the task group to pinpoint potential applications.
2. Evaluation of technology applications for each supportive function. This step consists of identifying CIM technologies that will satisfy the requirements developed earlier. Several technologies should be chosen for detailed evaluation with regard to each supportive function.
3. Determine which technologies will positively affect the largest percentage of functional areas. This step should identify technologies that will affect overall business operations, including some that were not identified as CSF supportive functions. Any CIM technology that significantly affects several areas should be investigated thoroughly.

Establishing Compatibility

The question of compatibility involves both the company's overall situation and technologies currently in use or under development in the company. Among the issues to be considered are:

- The skill levels required to operate and maintain the new technologies and their relation to the company's current personnel
- Compatibility of the identified technologies with the systems and equipment already in place. Often, new vendor-specific technologies adhere to different standards. For example, IBM has established PC-DOS as its standard operating system, but other microcomputer manufacturers are using a version of Unix.
- Compatibility of the identified technologies with the perceived direction of future technological developments. Utilization of expert consultation may be repaid several times over if it prevents a company from investing in obsolescent technology. (Duncan, 1985)

Improvement of Existing Procedures And Technologies

Although planning for CIM is emphasized in this thesis, simple procedural changes should not be overlooked. For example, eliminating the preparation of a time-consuming weekly report that is not utilized can represent substantial savings. The operational model can be utilized to identify such procedural inefficiencies in manual systems currently in place. A related topic is the automating of these manual systems in a manner that will integrate them with the overall objectives. (Young & Mayer, 1984)

Determining Functional Improvement Potential

The last step in the needs analysis is to assess each technology identified in the foregoing analyses in terms of its potential for improvement of operations and procedures. The factors to be investigated include:

- Reduction of throughput time
- Improvement of accuracy or quality
- Improvement in capacity utilization
- Reductions in processing steps
- Reductions in transmissions or transfers

- Reduction in generation of multiple sets of data pertaining to the same subject
- Reductions in costs associated with processing
- General capability for streamlining activities
- Capability of the technology for supplying features not previously available (Goldhar & Jelinek, 1983)

The factors most important to each CSF supporting function should be identified and used to quantify the impact of a particular technology on the performance of that function. An approximate percentage of improvement for each technology in each supporting function should be identified, even though this process will be relatively empirical.

One factor that almost invariably plays a role in decisions of this type is the reduction of costs associated with all business functions. The operational cost model will help identify the actual savings in direct as well as indirect labor. The model specifies mean processing times. The task group or accounting personnel can then assign dollar values associated with performing each function.

Once the percentage of improvement in all supportive functions has been established for each CIM technology, a matrix can again be utilized to determine the ranking for CIM technologies. One axis should identify the CIM technologies and the other the supportive functions. A new factor will be generated by multiplying the percentage improvement factor for each technology in each function by the rating of the supportive functions. The products are then summed for each CIM technology to arrive at the total improvement factor. The technologies can then be ranked in order of potential for improvement.

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CONCEPTUAL DESIGN

At this point the preliminary phases of CIM planning have provided the CIM task force with sufficient information regarding the company, its strategic objectives, and its internal operations to begin the actual designing of a CIM program. The conceptual design stage of the proposed CIM planning cycle consists of translating business requirements into specified sets of CIM technology applications.

In the past, CIM applications have followed the pattern used in development of computer systems. A team approach has been used in which each designer or design subteam concentrated on a single subsystem except for ascertaining that the system could be interfaced with those developed by other teams. This approach enabled several teams to work concurrently, thereby speeding the process of system development. It also ensured continuity in the event of a change in personnel. (Punwani, 1985) It has been suggested that the advantages of this approach are purchased at the expense of limitations in the scope of CIM development. (Gunn, 1976)

This thesis proposes, instead, that CIM design requires a holistic approach. It is suggested that the team approach be modified in such a way that an overview of the entire business be kept in mind throughout, and that the steering committee as well as specific task groups be involved throughout. In addition, the hiring of a design consultant with experience in the full cycle of the CIM planning process is likely to prove a sound investment. (Gunn 1986)

The eventual plan derived from the conceptual design stage will consist of sets of technologies and procedural changes integrated with the business operations. The resulting conceptual design will incorporate the technology and procedural change configuration that most effectively addresses the success factors found to be critical to the individual company's needs.

Establishing Alternative Scenarios

During the needs analysis, CIM applications and procedural changes were identified and CIM technologies were prioritized with respect to their expected contribution to achieving critical success factors (CSFs). In the conceptual design phase, these technology applications and procedural changes are

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Establishing Alternative Scenarios

During the needs analysis, CIM applications and procedural changes were identified and CIM technologies were prioritized with respect to their expected contribution to achieving critical success factors (CSFs). In the conceptual design phase, these technology applications and procedural changes are combined to address the business goals most effectively.

The development of a CIM plan is a creative process, and there is no single best method for achieving the business goals. (Gunn, 1986) The process of developing alternative technologies consists of more than simply combining those CIM technologies that have received the highest rating in terms of company needs. For example, the most highly rated equipment for automating a production process may be a proprietary system that does not interface with standard control systems. An alternative piece of equipment that is less highly rated in itself but that does interface with the control system already in place or selected for other reasons may be the best overall choice. Considerations of this kind should enter into all decisions if maximum benefit is to be obtained. (Punwani, 1985)

The proposed starting point for assimilating alternative scenarios into a conceptual design is to single out each critical success factor (CSF) identified for the company and identify the CIM technology that will have the maximum positive impact on that factor. Alternative scenarios can then be constructed in which additional, complementary CIM technologies and procedural changes are combined with these base technologies. The process continues until all the CSFs have been addressed.

The next major step proposed is to examine all alternative scenarios in order to establish a "best fit" between business needs and recommendations for functional improvement. In this manner, a single best conceptual design can be selected for further evaluation. One approach to this task would be to utilize the improvement potential factors established for each of the CIM technologies evaluated during the needs analysis. The scenario with the highest total score would appear to be the best choice. The resulting conceptual design should then be further evaluated from the perspectives of risk, resource requirements, and anticipated benefit.

Risk Analysis

The risks associated with the remaining scenario constitute an important perspective to consider in developing the conceptual design. Risk analysis will consist of two phases: (1) establishing general risks associated with the technologies and the associated procedural changes and (2) translating those risks into economic impact projections in the course of the cost/benefit analysis.

Establishing Intangible Risks

The first phase of the risk analysis will mainly establish intangible risks. It will examine the functional improvement potentials established earlier to determine worst-case, best-case, and conservative estimates of the expected results of implementing CIM technologies. The risks associated with attaining functional improvement potential and achieving the business objectives should be qualified.

To perform this first phase, the task group should examine each CIM technology present in the scenario to determine the risks associated with implementation and the compatibility of each technology with existing business operations. This detailed examination is necessary because each potential CIM application and procedural change may eventually become an implementation project, and its success will depend on careful planning. (Punwani, 1985)

Each improvement project must be assessed to determine the risk of failing to obtain the anticipated results, whether because of intangibles, economic conditions, legislation, human factors, or market conditions. The important point is to recognize the environmental factors that will affect these projects. The activities necessary to qualify these risks include:

- o Assessing the technological risk associated with each project. It may be necessary for task force members to attend CIM demonstrations or to observe the technology operating in a similar commercial environment.
- o Identifying additional risk factors for each project that could lead to failure to achieve the anticipated improvements, e.g., market conditions.
- o Performing an empirical sensitivity analysis to determine to what degree the improvement potential can be affected by actualization of a risk. Earlier in the planning cycle, percentage factors were assigned to the improvement potential inherent in each project. The task force must now estimate the extent to which the improvement potentials may be affected by risks in order

to identify best case/worst case conditions.

- Determining risk-management guidelines to increase the probability of success by focusing project management attention on the identified risk factors. (Muir, 1985)

Once these activities have been performed and the risks associated with each technology have been documented, the extent to which these risks could cumulatively affect the CSFs will be assessed. This last step will require the empirical judgment of the CIM steering committee.

Cost/Benefit Analysis

Up to this point, only potential benefits have been considered. It is now time to consider costs. Just as improvement potential consists of many seemingly intangible benefits, there are also intangible costs to be established for each improvement project. Once established, these costs must be quantified in economic terms. The cost/benefit analysis provides such quantification. It (1) identifies all costs, (2) compares costs with benefits, and (3) examines the time-dependent factors associated with realizing the benefits of CIM implementation.

More specifically, this process assists in (1) identifying those operational areas most likely to benefit financially from the introduction of enhanced manufacturing technologies, (2) evaluating the project economics of potential improvements, (3) evaluating the risk factors in relation to economic projections, and (4) establishing feasible overall expectations with respect to the projected results. (Savage, 1985)

The cost/benefit analysis will utilize much of the information developed during the "As Is" and needs analyses. The task group should not undertake this step without the assistance of thepersonnel who will be directly affected by the proposed changes. Their insight and support will be essential. **FN

The major activities of the cost/benefit analysis are described below.

Identifying All Relevant Costs. This activity includes quantification of all costs associated with performing the current related functions and all projected costs for implementing the new technologies and performing the related functions once the improvements have been implemented.

The first step involves referencing the operational cost model developed earlier to establish

"As Is" cost baselines for performing the activities presently associated with the targeted improvement area. The second step will be to establish a "To Be" cost baseline for performing activities related to the project area and to identify (1) nonrecurring costs and (2) recurring costs associated with project implementation. For example, actual procurement costs for equipment and software are tangible, nonrecurring costs to which a dollar value can be readily assigned. Other, less readily quantified nonrecurring costs include site preparation, initial personnel training, initial information systems links, and general implementation.

Costs that will be incurred on an ongoing basis include maintenance of hardware and software, supplies, personnel, ongoing training, software development, and the basic costs of performing the activities associated with a new way of operating in the affected areas. These last are important to establish but difficult to predict. Once again, the operating cost model will serve as the analytical tool.

Developing a "To Be" Cost Model. The next major activity is to assess all activities affected by the improvement products in order to develop a new "To Be" operational cost model for the conceptual design. Personnel who actually work with the activities should be involved in this process. Combining the task group's focus on improvement potential with the operating personnel's familiarity with the activities should produce useful estimates of operating conditions with respect to the proposed conceptual design. (Gunn, 1986)

Establishing Overall Economic Impact. Improvement potentials for each of the CIM technology application projects were established during the needs analysis in the form of percentages of improvement as measured by their estimated positive impact on CSFs. That exercise dealt mainly with assessing general intangible improvements. The remaining task is to assign tangible economic impact values, i.e., estimated cost savings and income-generating potential, to these general assessments.

The "To Be" operational cost model will facilitate the determination of cost savings. Differences in cost between current activities and those proposed in the "To Be" conceptual design can be assessed by individual improvement project and by overall impact on business operations. These savings will predominantly reflect savings in direct and indirect labor.

Assigning a profit-generating potential to the individual projects and the overall conceptual design will be more difficult. A company's profit potential might be improved in various ways: By improving customer service, thereby increasing sales volume; by improving production and inventory control systems, thereby reducing inventory carrying costs; or by improving engineering capabilities through computer-aided engineering packages (CAE), thereby reducing product-development lead time, permitting the firm to establish market share while the market is most profitable and, in addition, reducing the number of costly product-testing cycles. To assess these and similar intangible benefits, the task group must consult the personnel most capable of making impact estimates.

Performing an Economic Risk/Sensitivity Analysis. Once the basic economic costs and benefits have been established, the task force should assess the potential economic effects of previously identified risks. During the risk analysis, best-case, worst-case, and conservative estimates of the projects were established in terms of the actualization of risks. The economic benefits established in the foregoing step were presumably based on a conservative estimate of the positive impact of the improvement project. That information should now be expanded to portray the best-case and worst-case economic impact of the associated risk factors. This activity will establish risk-adjusted savings relevant to each improvement project by means of a sensitivity analysis.

An example of a sensitivity analysis is furnished by work done by IBM's Computer Integrated Manufacturing Systems (CIMS) group in Boca Raton, Florida. (Stern, 1985) This consulting group undertook to justify a $30 million capital investment in a new production facility. The data presented in Table 1 were

Table 1: Example of a Sensitivity Analysis

Item	Projected Change	Effect on IRR
Material cost	$1.00	3%
Material inflation	1%	3%
Start delay	1 year	3%
	2 years	10%
Additional production	1 year	9%
	2 years	17%
Decreased production	-10%	5%
Additional capital	$1 million year 1	2%
	Contingency (10%)	3%
Spare parts	+ 2%	5%

used in part to determine whether certain manufacturing operations should be implemented "in house" or whether the company should continue procuring the product from an outside manufacturer.

The assumption underlying the technique is that each incremental change in one of the assumptions underlying the costs associated with the project will produce a change in the internal rate of return (IRR). In the case of IBM, the investigation of the base situation had determined that the alternative of internal manufacture was favorable and would provide a 40 percent IRR. The sensitivity analysis calculated the effect on this rate of each of the listed changes.

The situation presented here is sufficiently similar to what is required for CIM implementation analysis to provide a useful example of the technique, which may be utilized by the CIM task force to test the impact of risk actualization on benefit projections. (Stern, 1985)

Establishing Cost/Benefit Trade-Offs. This activity documents the trade-off decisions that must be made when specifying the proposed CIM system. (Bravoco, 1985) The degree to which each operation or functional activity should be automated or integrated must be established by weighing costs against benefits to established a value-oriented conceptual design. The objective is to determine the point of optimal benefit so as to guard against a tendency to specify optimum automation without regard to costs versus returns.

For example, a banking organization studied its customer inquiry system to determine a customer satisfaction curve. The shape of this curve demonstrated that a clearly significant value could be added by upgrading the inquiry so that turnaround time for providing information was one day. The study also determined that upgrading the system sufficiently to achieve real-time response would provide only marginally greater customer satisfaction while costing significantly more. Investment.in the one-day system created a dramatic competitive advantage that was used to break a logjam of competitive entrenchment in the industry. (Elvia, 1985)

Trade-offs should be assessed for all of the improvement projects to maximize their value to the company. The "To Be" design may then be altered slightly to achieve a maximum benefit:cost ratio.

Identifying Time-Dependent Factors. The time-phased economics of each improvement project should be identified and the information used during the master plan phase to develop time-phased cash flow projections. Up-front costs should be summarized, a schedule of ongoing operational and related costs provided, and the time-phased attainment of projected economic benefits determined.

Up-front costs and ongoing operational costs may be readily summarized on the basis of the previously computed cost identification. These costs can then be simply presented for the entire conceptual design portraying a five- to ten-year projected cash flow. These projections will include wage rates, overhead rates, wage and sales growth rates, tax rates, tax credits, anticipated equipment life, equipment cost, materials costs, start-up costs, and maintenance costs. (Productivity International, 1981).

Time-phased attainment of economic benefits will be more difficult to establish, however. The attainment of benefits will necessarily be gradual. (Productivity International, 1981). The learning curve of personnel utilizing the new technologies must be considered, and problems associated with new systems and equipment will have to be eliminated before the expected benefits can be experienced. Therefore, the time required to realize benefits from each improvement project cannot be predicted with a high degree of accuracy.

A survey undertaken by the Canadian Institute of Metal Working suggests that the time required for attaining expected results may be conservatively estimated at 24 months. (Conkol, 1985) This survey encompassed 51 Canadian and U.S. companies. The time required to reach 300 percent productivity for engineering- and manufacturing-related CAD/CAM tasks ranged from 12 to 24 months, while the mean time for reaching 80 percent proficiency at selected CAD/CAM tasks was 18 months (see Figures 18, 19, and 20). Proficiency was defined as the ability to utilize all capabilities of the system and to apply those capabilities to specific tasks. A proficiency level of 80 percent should suffice to provide conservatively estimated benefits.

Although these survey results can serve as a starting point for estimating the time required to attain economic benefits, the task force should use their judgment in assessing each project and deriving estimates on the basis of that project's complexity.

Figure 18: Time Span to Achieve 300% Productivity In Manufacturing-Related CAD/CAM Tasks (From Conkol, 1985)

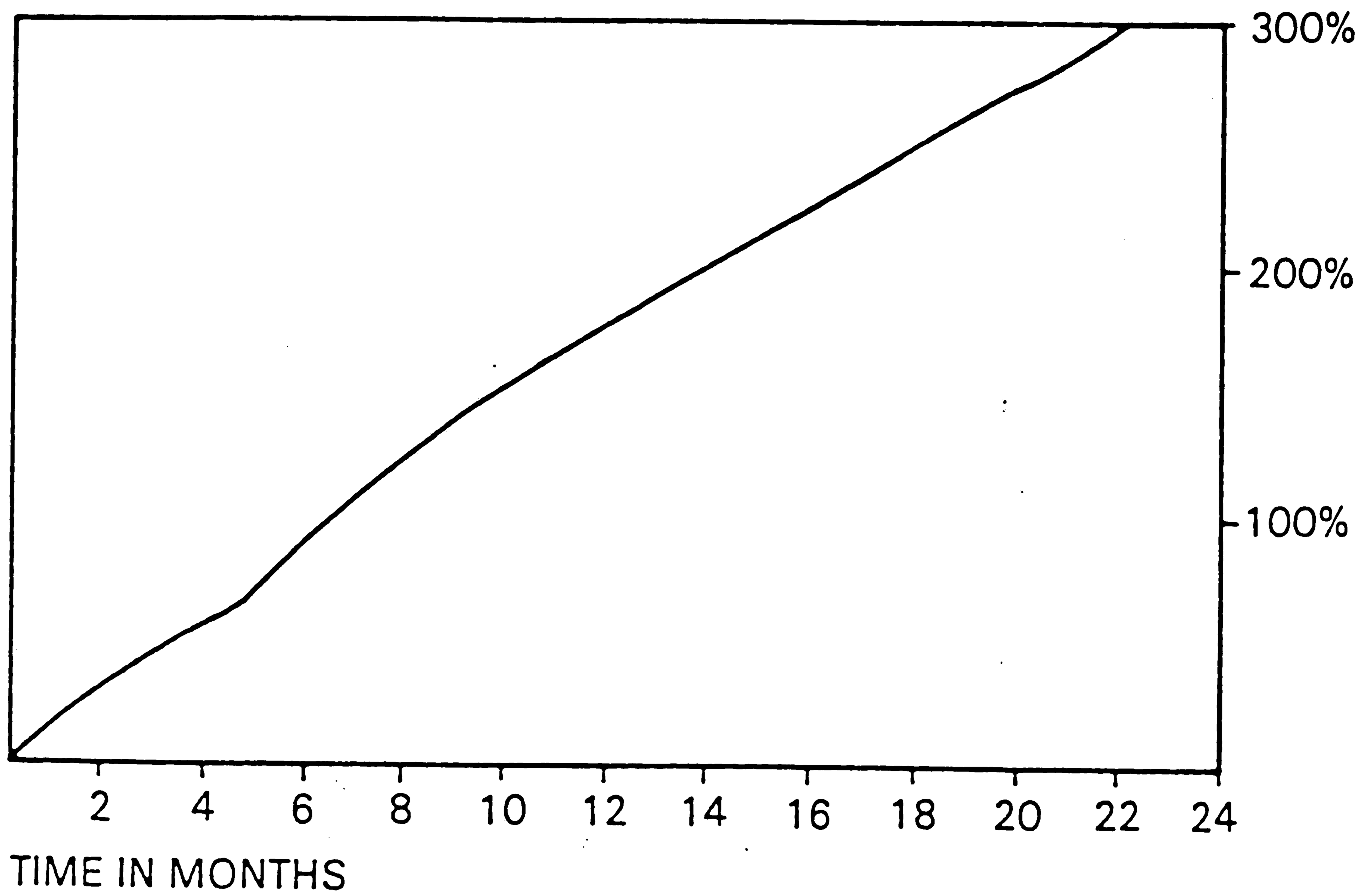


Figure 19: Time Span to Achieve 300% Productivity In Engineering-Related CAD/CAM Tasks (From Conkol, 1985)

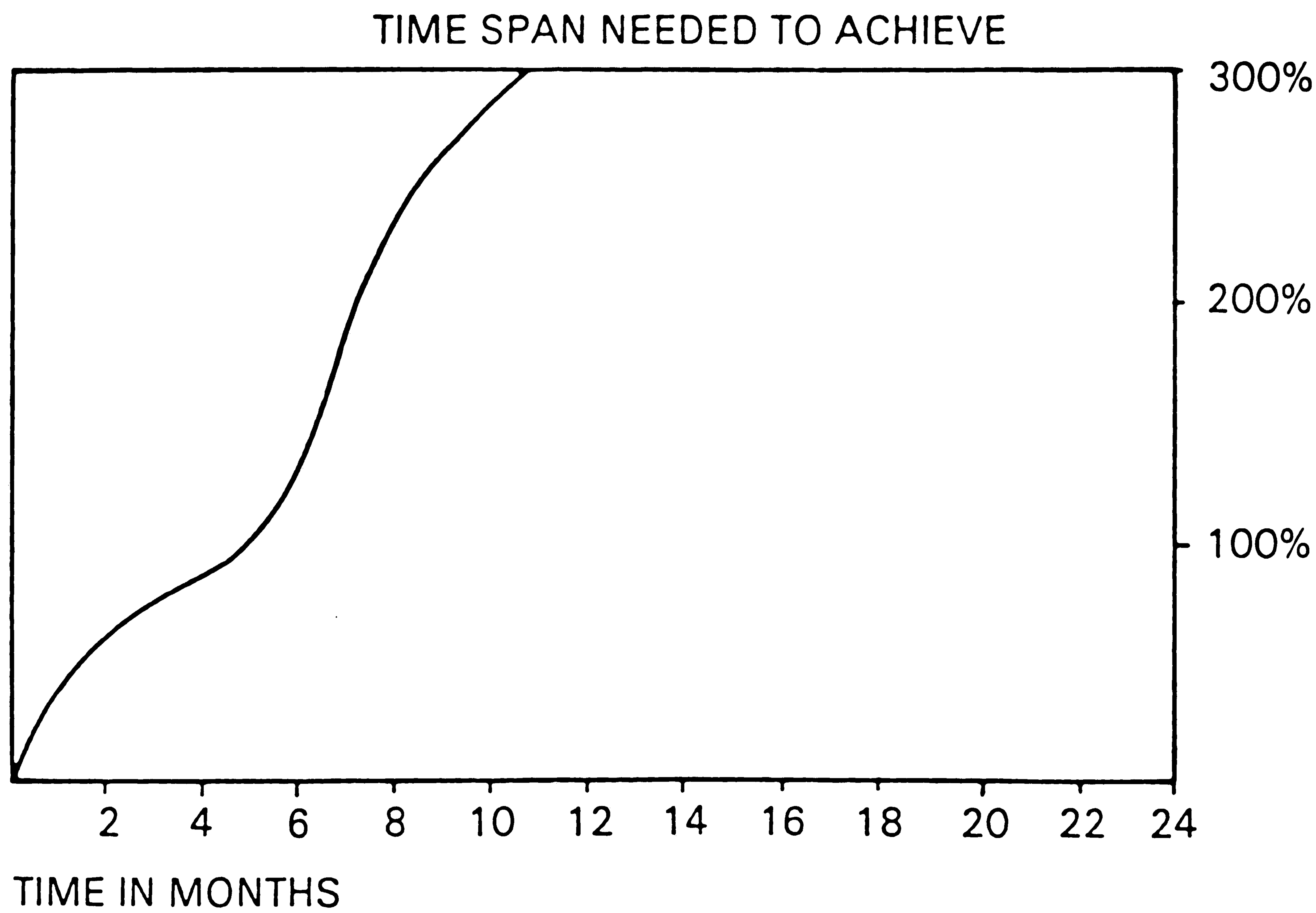
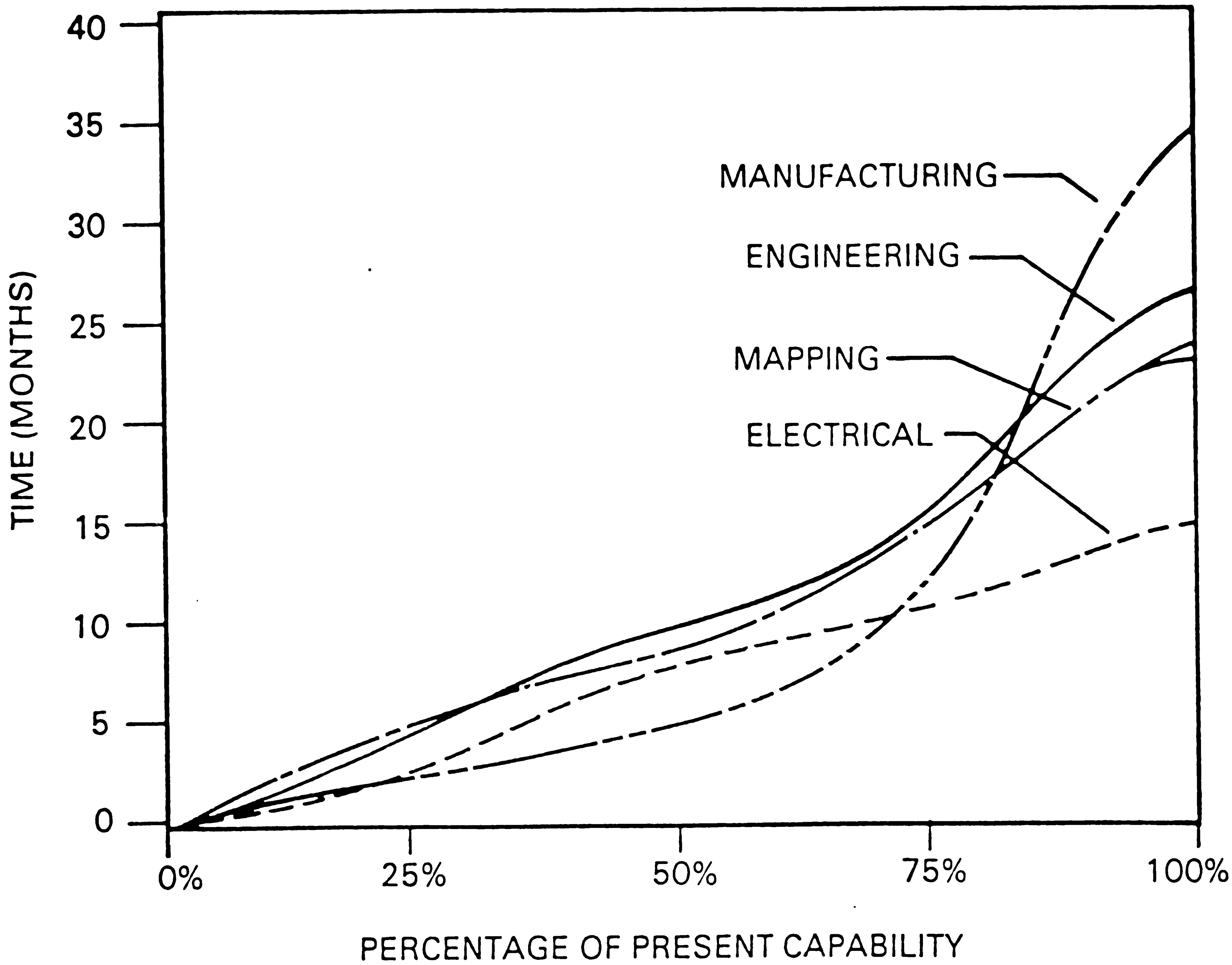


Figure 20: Proficiency Increases Over Time
(From Conkol, 1985)



In addition to estimating the timed attainment of efficiency or productivity, judgments will also have to be made regarding such considerations as attainment of increased sales and/or reductions in inventories. Personnel who specialize in the particular area of interest should be involved in making these judgments.

Developing Cash Flow and Financial Proposals. Completion of the foregoing activity will enable the task force to project cash flows for each improvement project over an extended time period as part of the financial justification proposal. The cash flow projections should indicate up-front costs, compare "To Be" with "As Is" conditions, and identify all projected benefits, thus providing a useful format for economic analysis.

Once all the economic benefits have been assessed and the conceptual design has been completed, the task group will need to develop financial proposals to justify the improvement projects to the CIM steering committee. This will require quantification in financial terms, because the contemplated improvement projects will be competing with other company investment decisions for the same limited corporate funds. (Bennett, 1985)

Identifying Cost/Benefit Tracking Requirements. The purpose of this step is to provide for closure of the planning control loop as necessary to monitor the benefits actually realized. During the master plan stage, it will be necessary to establish mechanisms for monitoring actual performance and comparing it with estimated improvements. The timing for attainment of estimated benefits will already have been established for each improvement project. The tracking-requirements step should further identify measurement criteria for this operation. A planned schedule for benefit attainment with annual or biannual targets should be set at this time.

Advantages of the Cost/Benefit Analysis. Each step in the cost/benefit analysis will enable the CIM task force to make fine adjustments in the overall conceptual design. Although it is difficult to quantify intangible benefits, it is also true that CIM installations generally pay for themselves through direct time savings alone. (Productivity International, 1981). It is best, therefore, to be conservative in estimating intangible benefits in order not to foster unrealistic expectations. The methodology described should produce realistic estimates of cost reductions and thereby provide a sound basis from which to perform an overall analysis of the impact of CIM implementation on a given business. (Muir, 1985)

Refining the Conceptual Design

The preliminary conceptual design must now undergo a series of specific and overall refinements based on the preceding analyses. Three phases are involved in refining the conceptual design.

Phase 1. The improvement projects must be refined to take into account the new insights gained in the risk and cost/benefit analyses. The task force will first examine the basic technological risks associated with each improvement project to ensure its general feasibility by altering project scope as indicated. The cost/benefit analysis is then reviewed to assess whether the projects can be further refined to improve their economic impact. Then, the task force must make a final determination of which functions are the best candidates for computerization or automation and which are better performed manually. (Schneiderman, 1981)

Phase 2. The improvement projects should now be refined so as to form a complementary combination of related functional areas. The task force should ensure that each improvement project will provide the required information for or input to the functions that succeed it in the line of processing. In addition, it is important to facilitate the greatest possible compatibility with existing and proposed systems.

Phase 3. The contribution of each improvement project to the strategic goals of the business should be reviewed and the project revised accordingly. The overall objective is to integrate the efforts of all functional groups in the firm so as to provide the greatest overall benefit.

Not all the contemplated improvement products will require revisions. However, performing any necessary refinements during the conceptual design stage is far less costly than making modifications during or after implementation. Provided that the data compiled by the task groups is accurate and comprehensive, the few revisions that will be required will constitute a final evaluation rather than a total redesign.

As required revisions are performed, all documentation should be updated accordingly, especially the "To Be" operational model and the cost/benefit analysis. The procedures utilized in originally performing these analyses--for example, application of sensitivity factors--will facilitate the updating process.

Presentation of the Conceptual Design

The conceptual design of the proposed CIM program has now been refined and validated in its final form. The task remaining is presentation of the design to the steering committee, senior management, and the company "stakeholders." The purpose of the presentation is to orient these individuals toward the new mode of operation.

Presentation to the Steering Committee

The first priority of the task force will be to familiarize the steering committee with the features of the conceptual design such as new systems, personnel interfaces with those systems, discrete improvement projects, the projected benefits of economic and business growth, and the major differences in operation between "As Is" and "To Be." A detailed projection of costs and benefits associated with each improvement project should also be presented.

The CIM steering committee has had a limited involvement with the actual planning activities. Their principal participation has been in major decisions such as determining the CIM project leadership, initial allocations of manpower, and determination of the critical success factors for the enterprise. At this point, they must be familiarized with the entire conceptual design, in detail.

Tools of Presentation. Pictorial and graphical presentations may be utilized for effective presentation. The major concepts of the design may be communicated through condensed graphics, flow charts, tables, and pictorial representations. Summarizing the models and documentation generated during the planning process is a good starting point. For example, the "To Be" information flow can be simplified to depict the major forms of information that are transmitted between functional areas. The actual CIM systems and equipment can be graphically portrayed in their proposed facility locations and the electronic links depicted. The tables prepared during the cost/benefit analysis can be presented in the form of charts and overheads.

The Importance of Quality. Quality of the presentations is important to both comprehension and acceptance. (Bennett, 1985; Bravoco, 1985) The conceptual scenario must convey the impression of thorough engineering design. Careful preparation will permit the conceptual design to succeed on its merits, invoking a sense of ownership in the steering committee that will affect their eventual presentation to senior management and stakeholders.

Presentation to Senior Management

Members of the steering committee, augmented by key members of the task force, must then prepare a succinct presentation for major shareholders and those senior managers who arenot members of the steering committee. An overview of the conceptual design and relevant business and technical issues should be presented, with emphasis on financial returns and business growth potential. Graphics may be used to convey the conceptual design, but the emphasis should be on charts depicting economic benefits and growth projections. (Muir, 1985)

Senior management will have additional concerns. Labor relations may be a major issue. Research indicates that totally integrated CIM installations produce considerable benefits without eliminating employees because the volume of business tends to increase significantly without necessity for additional staff. (Elvia, 1985) Senior management may begin considering options for relocating displaced employees into areas of the facility where activity can be expected to increase as a result of the CIM program.

A Model Conceptual Design

An example of an effective conceptual design is provided by the experience of the General Electric Company. (Snyder, 1985) The steam turbine/generator division of GE, needing to increase its level of manufacturing flexibility and customer service, participated in a CIM planning effort that focused on improving competitiveness over a ten-year period. GE developed the following eight modules, which constitute their conceptual design:

- Marketing systems that provide instantaneous quotes and on-line order entry, forecast demand, and manage complex international projects
- Business systems employing the latest Manufacturing Resource Planning II (MRP II) concepts
- Engineering design systems employing

interactive graphics and design programs and generating digital codes that provide complete descriptions of parts for use by other functions, i.e., the basis of an integrated database

- A generative, automated process planning system that captures planning logic in an expert-type system to route parts most efficiently through the manufacturing shops
- A numerical control (NC) programming system employing the latest techniques to instruct machine tools on how to cut complex parts
- A factory management system that provides distributed numerical control, factory communications among the work stations and their support functions, and shop floor control modules that track each piece through the shop and the resources applied to it
- Automation systems employing the latest computer numerically controlled machine tools in flexible manufacturing cells serviced by robots
- Professional productivity programs based on broad use of networked personal computers

Each of these major modules presents significant challenges in itself, but the major CIM challenge is integrating these systems into a synergistic whole. (Snyder, 1985)

The point of this example in regard to this thesis is that GE's investment in this plan was based on presentation of a thorough conceptual plan to senior management. (Snyder, 1985) In presenting a CIM plan in accordance with the methodology presented in this paper, the task force will need similarly to present a comprehensive conceptual design and to solicit the response of senior management to that design before proceeding with the final step, which is the development and presentation of a master plan for the CIM implementation.

DEVELOPMENT OF THE MASTER PLAN

The final stage in the development of the strategic CIM plan is the organization of the approved conceptual design into an appropriate master plan for CIM implementation. Having completed the conceptual design stage, the company management and task force now have a clear statement of a CIM strategy that will support the business goals and critical success factors. (Punwani, 1985)

The master plan will consist of a detailed set of action plans. The general approach to developing action plans and translating those plans into an evolutionary CIM program is presented in this section. Once the master plan is developed, the company's managers and the CIM task force will have a charter with which to guide their CIM implementation. This charter will provide:

- Direction for the final program implementation activities
- The means to control, monitor, report on, and make decisions about CIM program progress
- The means to assign accountability to area managers and task force members on a project and overall program basis

- **Direction for the development of the** necessary records, management standards and practices to ensure the effective utilization of the new CIM implementations

During the master plan development stage, the individual improvement projects will be transformed into CIM program modules, the factors affecting integration of these modules with the business operations will be analyzed, each module will be evaluated, and a time-phased plan for module implementation will be developed.

The master plan will address such questions as:

- Which modules will be implemented first?
- When will each module be implemented?
- Who will be responsible for the various stages of the implementation?
- What resources will be required for the implementation of the CIM program?

Once completed, the master plan will provide the means for the company to make a smooth transition from the current mode of operation to a new, more competitive business operation.

Formulation of the Integration Strategy

One of the major underlying premises that have been stressed throughout this thesis is the importance of business-wide integration. The CIM program will serve as a vehicle for achieving this level of integration. In order for this to happen, the CIM program should have the characteristics of a tightly integrated plan. The next activity that the company management and CIM task force should undertake will therefore be to formulate the CIM integration strategy.

As a starting point, the task force should develop an overall integration policy. In general terms, the company's managers and task force members must formulate a policy for networking technology, people, management, and knowledge workers into an effective, flexible and responsive organization. (Savage, 1985a)

This policy should be a short summary of the integration goals for the company developed with strategic business objectives in mind. It should establish the extent to which company management have determined that operations must be integrated in order to positively affect overall business competitiveness. An integration policy will provide a solid basis for deriving implementation guidelines. (Savage, 1985b)

Development of CIM Modules

With the general integration policy in mind, the task force should focus their attention on the specific improvement projects that make up the conceptual design. The projects that were presented earlier should be examined to determine their ability to operate as distinct modules. This activity will involve making logical combinations of small improvement projects in some cases, while other projects may constitute distinct CIM modules by themselves.

Additional factors that should be considered during the establishment of distinct CIM modules include (1) the dependence (technical or otherwise) of the improvement projects on other such projects, (2) logistics relevant to implementation, i.e., whether the improvement project can be discretely implemented and still provide benefits, and (3) time considerations such as keeping the implementation projects manageable (the implementation period should be six months or less). (Appleton, 1985) The determination of distinct CIM modules will facilitate a well-planned, smooth implementation of the CIM program.

Establishing Integration Between Modules

The next consideration is to evaluate the feasibility of integration between modules. The task force must establish the extent to which the CIM modules can be integrated and what the requirements for accomplishing the integration will be. Since information flow is key to the concept of integration, the task force should begin by examining the necessary communication linkages between various CIM modules and existing systems.

An effective CIM program requires that business information be viewed as an enterprise-wide corporate resource encompassing manual and computer storage and processing. (Young & Mayer, 1984) Therefore, the task force must ensure that each CIM module can communicate information between existing systems and other proposed CIM modules. Integration and informational handling aspects have been emphasized throughout the planning stages, so no major problems should be discovered during this activity. Rather, it should serve as a check for such problems. Integration aspects between modules should be investigated to provide implementation planning for their eventual interfacing.

Developing an Informational Architecture

An informational architecture for the enterprise must be developed at this stage to support the CIM modules and the new mode of business operations. This will require an understanding of the planned informational hierarchy as depicted by the "To Be" operational model of the company. The top level of the hierarchy will consist of the primary informational requirements of senior management. Senior managers must acquire key knowledge about the operating characteristics of their company in order to make key decisions. In most companies the information required to derive this knowledge is generated through a chain of events that begins at the functional levels of the company and must be directed and compiled upward through the ranks of the company. This series of events tends to be highly dependent on manual processing and compilation. (Young & Mayer, 1984)

The informational architecture should be planned for maximum facilitation of the transfer and compilation of information along the line of information flow through the company, thus providing for more effective business operation. An informational architecture should facilitate information transfer by eliminating some of the reliance on people for mundane information-handling tasks and freeing them for more important decision-making activities.

The CIM planning methodology presented in this thesis specifically addresses the establishment of a hierarchy of informational and functional needs throughout a manufacturing enterprise. The point that is stressed here is that an informational architecture should now be planned in which informational linkages of CIM modules will facilitate the logical integration of the business operations and provide enhanced support for all functions within the company. (See Figure 21.)

Issues the informational architecture must address include (1) communication and networking schemes in addition to (2) database configuration. Actual computer hardware and software requirements presumably have been addressed in the conceptual design of each improvement project. These two major areas require input from individuals with in-depth knowledge of information systems and new CIM technology developments. It is rare for a small to medium-sized company to have such an individual or group of

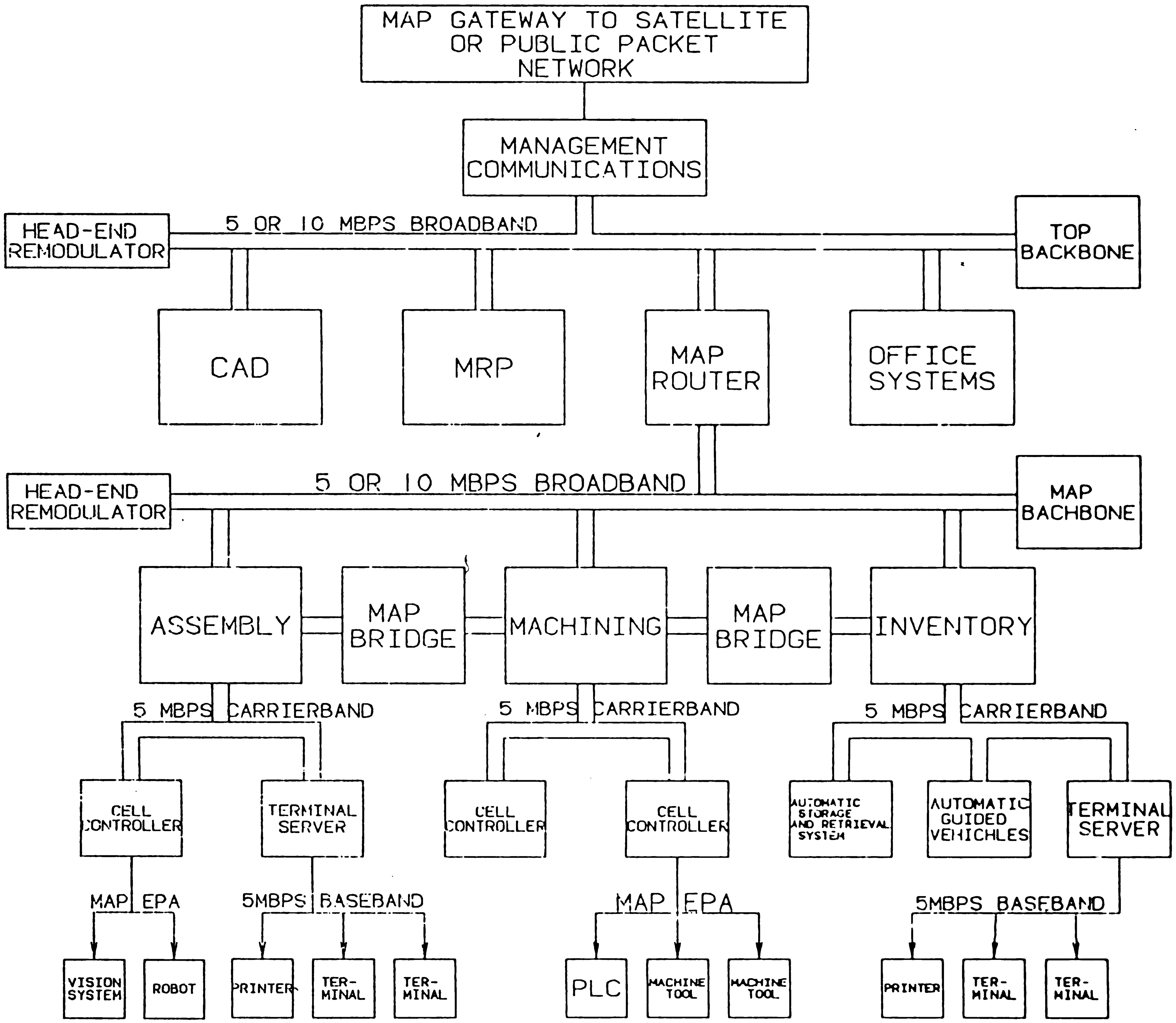


Figure 21: Example of a Communications Scheme (Stickler, Mark, "CIM Lab Communication Scheme," Prepared for Lehigh University CIM Lab, 1987)

individuals "in house," especially those who have experienced the full gamut of a CIM implementation. It is suggested that a company involve CIM experts/ consultants when developing the CIM-oriented informational architecture.

Developing an informational architecture will clearly establish the interfaces between various CIM modules and existing systems that are necessary for maximal facilitation of the organized integration of the business operations.

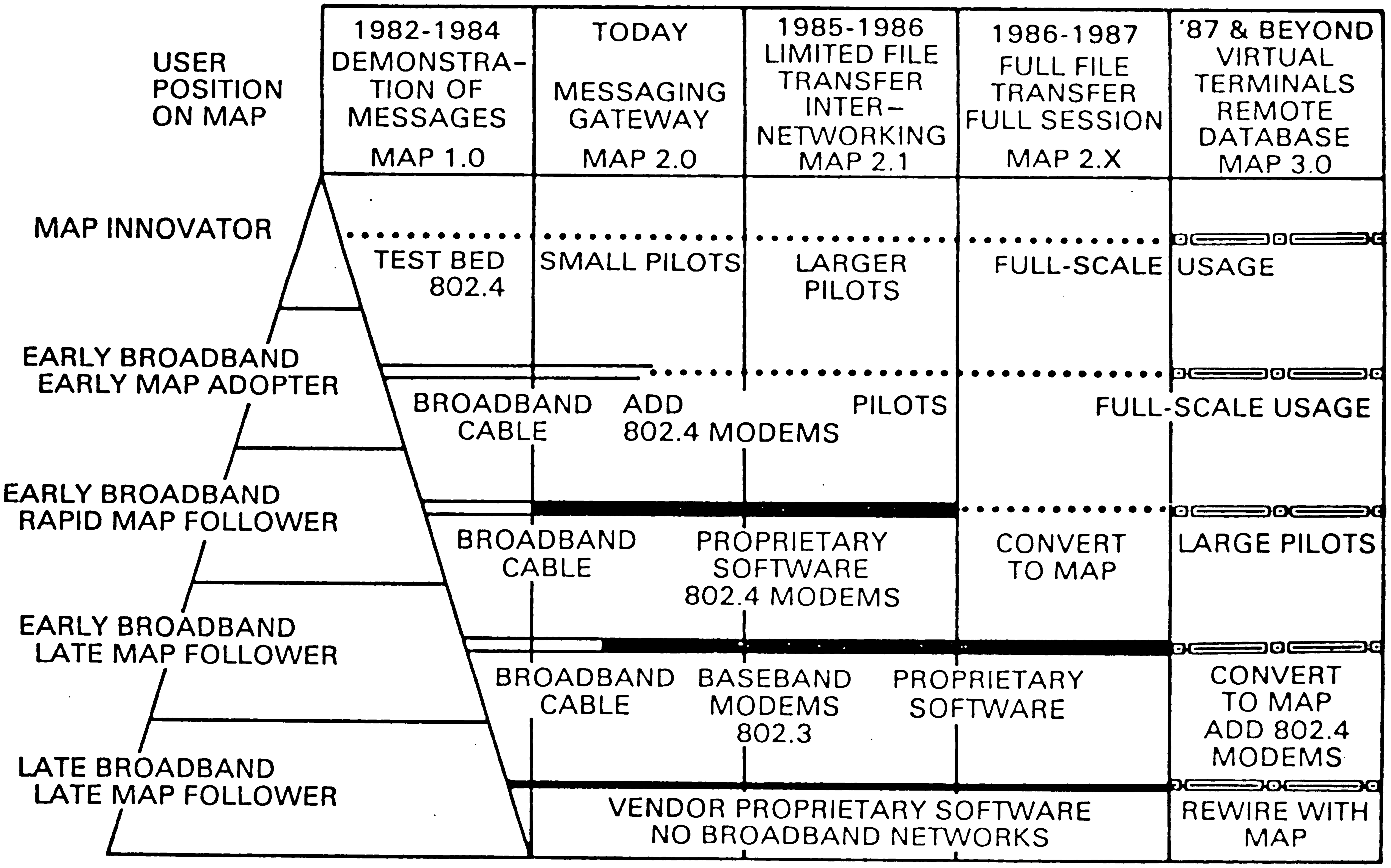
Specifying Protocols and Standards

A major consideration in the development of the informational architecture includes the specification of communication protocols and corporate standards. The CIM task force should review the various modules for application of industry-based and functionally related standards. The CIM implementation must support appropriate industry protocols and standards. This support can be ensured by setting standards for the corporation prior to the implementation of the CIM program and by complying with these standards during purchasing of equipment and software packages.

The specific standards that the company may choose to support will be determined in part by the nature of its business activities. The task force should investigate standards that have been established in the technical areas relevant to their particular CIM implementation. They must also identify the standards currently in use in the company and assess their probable future status, i.e., whether they will remain an industry standard.

Through this activity the task force should choose existing and emerging standards that match the company's situation. Four major examples of established communication standards in industry described below. (Savage, 1985c)

Manufacturing Automation Protocol (MAP). MAP is a prominent standard that is undergoing continual development. It is a collection of existing and emerging communications protocols, each of which has been developed by a standard-setting body. The MAP has been developed by General Motors and is based on the work of other groups including the Institute of Electrical and Electronic Engineers Standards Committee 802, the National Bureau of Standards, and the International Standards Organization. The goal of MAP is low-cost multivendor data communications (Figure 22).



Adapted from a chart by Paul Accampo, Product Manager
Hewlett-Packard Roseville Networks Division.
Presented at the 2nd MAP Users Group Meeting, Jan. 85.

Full Function Network
Limited Intervendor Network
Full Intervendor Network

Figure 22: Outline of MAP Protocol Progress (From Hales, 1985)

MAP is now being augmented by TOP (Technical and Office Protocol), an attempt to address the need to communicate between the technical and office-oriented functions of a company. (Hales, 1985)

Initial Graphics Exchange Standard (IGES). In the field of computer-aided design (CAD), transfer of information between different makes of CAD systems is complicated by the fact that vendors format their data in different ways. IGES is an established standard that seeks to overcome this problem. IGES provides a neutral data file that is passed between systems and translated upon receipt. Because of the great differences between CAD systems, however, IGES does not always do a complete job. An effort is under way to develop IGES-PDES (Product Design Exchange Standard) in which certain capabilities are provided to address the perceived weaknesses of early versions of IGES.

Electronic Design Interchange Format (EDIF). CAD information for the microelectronics industry is significantly different in format from that used in the mechanical parts manufacturing industry. Leading vendors in the electrical field are promoting EDIF as a means of communicating design information between systems, test equipment, and production equipment. (Hales, 1985)

Business Data Interchange (BDI). BDI is another emerging standard of potential interest to all industry groups. The goal of BDI is to facilitate order processing, shipping and receiving, invoicing, and payments between separate firms. With increasing emphasis on close supplier links, just-in-time scheduling, and more frequent order cycles, the importance of BDI will grow. (Hales, 1985)

Many additional standards are being defined for data communications, graphics, robotics programming, and other related CIM technologies. These standards should also be investigated by the task force to determine their applicability to the company's master plan.

Once all the relevant technological standards have been identified and established, the task force can complete the development of the informational architecture for the company. It will include a hierarchical scheme of communication protocols, network configurations, database schemes, and technological standards which will facilitate the company's planned transition to an integrated business operation.

With the informational architecture for the company complete, the task force can make equipment purchase decisions based on the capability to integrate that technology with the firm's overall business operation. Taking such factors into consideration during the planning stages will help avert problems during implementation.

The activities discussed--setting the company integration policy, determining distinct CIM modules for implementation, developing an informational architecture, and setting company standards--will serve to formulate the company integration strategy. By establishing a integration strategy, company management and the CIM task force will facilitate the smooth implementation of the CIM program.

Evaluation of the CIM Modules

In order for the executives of a business firm to authorize a CIM plan and invest in its implementation, it will be necessary to justify each CIM module to them. The cost/benefit analysis of the conceptual design stage has established the economic impact of each improvement project. At this stage, especially in cases where different projects were combined to form CIM modules, each module will be subjected to a final evaluation to determine whether it will in fact be implemented. The CIM module evaluation step consists of evaluating each module with respect to implementation characteristics, risk, economic benefits, nonfinancial considerations, and finally to determine its priority for implementation in relation to the other modules.

The primary objective of this step is to minimize the risk of the company's investment in the CIM program and to demonstrate to the company executives that this has in fact been done. The CIM module evaluation procedure consists of (1) establishing implementation considerations, (2) identifying all benefits associated with the new scenario, (3) determining which CIM modules will form the basis of the program, and (4) prioritizing modules for implementation.

Establishing Implementation Considerations

Important considerations regarding the implementation include ease of implementation and risks associated with implementation. In order to determine the ease of implementation, the CIM task force should determine the steps required for implementation. This will require the task force to study each CIM module and establish the necessary steps to implementation. Having the task groups who initially investigated the technologies conduct this study will streamline this activity. The implementation steps need not be determined in great detail. Rather, a good estimate the work required and the time associated with each step will be sufficient. Through this activity the task force can investigate such considerations as the technical support required for implementation and the ability of available company personnel to implement a module without outside assistance.

In addition, implementation risks must also be determined. Many of the risks directly pertaining to the implementation projects have been established in the conceptual design stage, but risks associated with the implementation process must also be established in order to properly evaluate CIM module implementation.

To complete this evaluation step the task force should assign ease of implementation factors to each of the CIM modules. This factors should be empirically assigned to the modules to designate the likelihood of a smooth implementation without complications or underlying risks. The higher the factor, the lower the risks.

Identifying Benefits of the New Scenario

This step consists of (1) updating the cost/benefit analysis results to reflect the new combinations of projects and (2) assessing nonfinancial criteria pertaining to the CIM modules. The task group must combine the associated costs and benefits of the improvement projects that make up the CIM modules. However, not all benefits will have a short-term impact on financial returns. The company managers will have to consider other criteria for justifying the CIM modules. For those CIM modules that do not meet the company's minimum return on investment, managers must ask, "What will the effect be on the company as a whole if we don't invest in (and learn to use) this new CIM technology?" (Elvia, 1985)

Other potential nonfinancial benefits that should be considered during this stage of activity include (1) more accurate information, (2) more timely information, (3) improved managerial decision making, (4) easier information retrieval, and (5) enhanced sophistication of analytical tools. Although difficult to quantify, these and similar factors in fact have a strong potential for strategic impact. In addition, certain CIM modules that do promise excellent return on investment may depend on other modules that do not.

The task force should assign financial and nonfinancial benefit factors to each of the CIM modules. These factors should be empirically determined. The financial figures can be assigned based on the benefit:cost ratio. The nonfinancial factors can be assigned by reviewing the results from the needs analysis stage where positive impact on CSFs was established and by determining the dependence of other modules on the modules being assessed. In this step a high value will represent a large potential benefit from implementation. The factors derived in this step and in the previous step will be used later, in the time-phased implementation planning procedure.

Determining the Base Modules

It is necessary to determine which CIM modules will the basis of the CIM program. Other CIM modules will be added to the base modules as the CIM program gradually evolves. Since the needs analysis was performed in a top-down hierarchical manner, determining the base models should be a straightforward procedure. Base modules will be those that generate or collect critical business information. They will be implemented at the basic functional levels of the business. Examples of these types of CIM modules would be CAD systems, order entry systems, database management systems, etc. These CIM modules will provide the core information, data structures, or capabilities with which to build an integrated business operation.

Prioritizing Modules for Implementation

CIM module prioritization must not be the sole factor in determining the order of implementation, but it will formulate useful information for implementation decisions. High-priority modules should be those projects that are projected to have a high potential for strategic impact, a low risk, and satisfactory financial justification figures. CIM module prioritization is performed according to criteria established by the task force and senior management from the perspective of obtaining the greatest strategic leverage for a firm.

The CIM module evaluation activity will primarily be a review and summary of information developed earlier in the CIM planning cycle. By following the evaluation procedure the task force will be in a better position to effectively plan the implementation of the CIM program. When the CIM modules are evaluated and prioritized in such an organized and planned manner, the risk of unexpected problems during the implementation stage is significantly reduced. (Elvia, 1985)

Developing a Time-Phased Implementation Plan

A time-phased implementation plan will provide guidance for the company personnel throughout the implementation of the CIM program. The completion of the CIM module evaluation activity will provide a basis for the CIM task force members and company management to develop an implementation action plan. The action plan will provide a tactical approach for implementing the CIM modules that will comprise the core of the master plan for the CIM program.

In order to develop an action plan, the following steps will need to be enacted: (1) development of an implementation sequence, (2) determining timing of the implementation, (3) determining required resources, (4) setting implementation accountabilities, and (5) reviewing the action plan.

Developing an Implementation Sequence

In general, when planning a CIM module implementation sequence to achieve business objectives, the task force should first study the information that was developed in the CIM module evaluation activity. From this activity, the most logical sequential plan for implementing the CIM modules can be determined. This sequencing step is, in effect, mapping the route the company will take in order to accomplish the business objectives. (Productivity International, 1981)

In the model-evaluation step, the individual CIM modules were analyzed for logical interdependencies, and the time predicted for implementation was determined. It is vital that the master plan accommodate the progressive union of the different technology projects into an integrated long-term solution. Certain modules--for example, the CAD system and the engineering design database--should precede other dependent technology projects, such as computer-aided manufacturing, so that a suitable technology base is established for the longer-term CIM environment. (Punmani, 1985)

However, additional tactical issues besides the logical implementation order must be considered.

Management will be applying close scrutiny to the implementation of the first set of CIM modules to determine the wisdom of this investment. In addition, many company employees will be apprehensive about the first phase of the CIM program. For these reasons, the careful selection of the first few modules for implementation is mandatory.

The first CIM modules designated for implementation are critical in part because they set the stage for the future of the CIM program. Success with the first set of implementations increases the likelihood that the CIM program will be accepted and supported by senior management and company employees.

The first few CIM modules selected for implementation should have (1) a high ease-of-implementation factor, (2) low technological and implementation risks, (3) quickly demonstrable benefits, (4) base technology, and (5) high priority. Since it will be difficult to find CIM modules with all the desirable characteristics, those modules with low risk and highly visible projected benefits should be chosen above others.

Once the first set of CIM modules has been implemented successfully, the task force can implement some modules that are less ideal. The general order of implementation should build up the functional base of the company in a hierarchical manner. Not all the base CIM modules need be implemented first. The task force may choose to address a particular critical success factor before branching to other areas of concentration. What is important is to progessively erect the necessary technology bases for the higher-level CIM modules.

Other factors to consider throughout the development of the implementation sequence include:

- Balancing the module characteristics within implementation stages
- Delaying modules that affect changing aspects of the business until late in the implementation schedule
- Requirements for preliminary education and training

CIM modules should be balanced between high and low risk, short-term and long-term benefits, high and low return on investment, and ease and difficulty of implementation so as to maintain a steady flow of positive results. Any perceived hiatus in positive impact from the program may cause management to reconsider their position.

If a CIM module is to be implemented in a volatile area of the business, the implementation of that module should be delayed till late in the sequence. This move will allow changes to occur or a better assessment of the situation to be made at the later date.

Another very important aspect to consider with respect to implementation sequence will be education and training. Proper education and training in a CIM technology may not only be required for successful operation of a CIM module but it may also be required for the implementation of that module. In either case, any education and training required should precede the implementation of a CIM module.

Determining the Timing of Implementation

Once the sequence of CIM module implementation has been determined, the timing or schedule of module implementations can be developed. Utilizing the information developed in the CIM module evaluation activity (implementation steps and time estimates for each step were developed during that activity), the task force will be able to establish a timed sequence of module implementations.

Realistic completion dates must be assigned to each module implementation, because the realization of benefits for the company will be planned according to that schedule. With a rough estimate of available resources, the task force can establish the implementation schedule. Once the implementation effort has begun, the individual in charge will be responsible for meeting the delivery dates. Therefore, that individual and the people involved in the affected area must authorize the delivery date before it becomes part of the master plan timetable.

The final product of this effort should be a CIM module implementation timetable that documents the projected start and end dates for the implementation of each of the CIM modules and designates milestones for the completion of each step of a module implementation.

Determining Resource Requirements

The required resources must be allocated to meet the module implementation timetable. Resources can normally be categorized as (1) human effort and (2) resources. Human effort consists of the manpower required to perform the implementation tasks and manage the project. This resource area should be defined in terms of manhours required in different work categories such as management and task-level. Resources consist of all basic resources required in the implementation of CIM modules, such as organizational time, money, equipment, systems, any planning tools such as project management software packages, and so on. Often-overlooked resource requirements include company operational time and funds that will be spent working with vendors and consultants to implement the CIM modules. (Productivity International, 1981)

The CIM program timetable will provide the CIM project leaders with the information necessary for scheduling the required resources. The task force must now ensure that the resources that are necessary for module implementation and operational activities are in fact available. For example, the present organization skill base and projected workload need to be examined to determine whether additional employees are required for the CIM modules' implementation. In this case, the task force can refer to the work done in the CIM module evaluation activities to determine the necessary skills required.

The CIM module implementation planning activities should be approached as analytically and realistically as possible. (Productivity International, 1981) Once they have been completed, management will have an allocation schedule for the required resources.

Establishing Implementation Accountabily

This activity is results oriented. Area managers and project leaders are given the responsibility for implementing their respective CIM modules by the set deadlines. The best results are generally achieved if the task force project leader is the area manager of the site where the CIM module is being implemented. This individual will then be the driving force behind the implementation. (Gunn, 1986)

The project leader will assign responsibilities to individuals to provide the necessary technical support and to complete the task-level activities. Accountability will be assigned for each step and objective of the implementation.

Other areas of responsibility that the project leader assumes includes risk management and education and training. Risk management guidelines established in the conceptual design stage can provide a basis for developing a risk management program. This program should define how the implementation of the module should be managed to maximize the real benefits to the company and avoid potential pitfalls. (Punmani, 1985)

With respect to the issue of education and training, it is critical that the project leader address this responsibility objectively. Education and training have greater importance than many company managers initially realize. Many issues are involved in a CIM program besides connecting the equipment and operating the systems. One such issue is that of overcoming employees' natural resistance to change. Experience has shown that in many cases, education and training have reduced this resistance. (Gunn, 1986)

Responsibility for education and training should be assigned to individuals within the company. The project leaders must develop a plan for educating and training the personnel in their area. This plan will focus on the projected benefits, operation, utilization, and maintenance of the CIM modules to be implemented in their areas. Through participation in an education and training program, company personnel will learn to accept new technologies in the natural course of events.

Reviewing the Action Plan

The review process is logically the final step in preparing the action plan. In effect, those involved with the project take one last look at the plan before firmly presenting it to the company's executives. (Productivity International, 1981) 8] The task force should now review and, if necessary, revise each project leader's individual action plan as well as the action plan as a whole. The overall action plan should be tested (1) in an internal review by company managers and task-force members and (2) by outside consultants. These unbiased third parties should have technical competence and management expertise relevant to the company's industry, the latest technologies, and the effort required to accomplish a CIM implementation.

Overall, the plan should be precise but flexible. It should be noted that reviewing is an ongoing process throughout the implementation program to accommodate changes in strategic business objectives.

With the action plan complete, the task force can examine it to develop a schedule of cost/benefit accrual. This accrual schedule will serve as a principal tool in the development of mechanisms for monitoring performance. The time-phased cost/benefit accrual schedule developed during the conceptual design phase must be combined with the action plan in order to project the accrual of costs and benefits throughout the entire CIM program.

Developing Procedural Mechanisms for Monitoring Performance

The next step in the development of the master plan is to develop procedural mechanisms for monitoring actual performance against estimated performance. This step will provide program-implementation control mechanisms. As circumstances change, management and the CIM task force will be able to determine the point at which performance has fallen below projected levels, to identify problem areas, and to alter implementation plans as indicated.

The process of developing monitoring mechanisms and procedures consists of (1) developing tracking mechanisms, (2) establishing performance measures, (3) monitoring performance, and (4) developing mechanisms for implementation control.

Developing Tracking Mechanisms

The first phase in the development of monitoring mechanisms will be to establish which entities must be tracked in order to portray the status of the implementation program.

Establishing Tracking Requirements. In order to establish the tracking requirements, the task force must define the desired areas to be tracked. These areas usually include implementation schedule adherence, cost/benefit accrual timing, intangible benefits or positive impact of the module, and basic progress indicators. To answer the question "What types of information are required to track the status of the CIM program?" the task force should identify the factors that will consistently demonstrate the level of progress that the CIM program is achieving. The level of progress will be tracked with respect to the stated action plan and the strategic business objectives.

Identifying Sources of Tracking Information. Having established the types of information that will be necessary for progress tracking, the task force must now identify specific sources of the required information. Areas to be tracked and characteristic informational sources include:

- Implementation schedule adherence: The module implementation project leaders will provide the status information.
- Cost/benefit accrual timing: Existing

accounting systems and newly developed cost and benefit tracking systems will provide the necessary information.

- o Intangible benefits or positive impact: An empirical judgment will need to be made by the area manager and task force members.
- o General progress indicators: The source will depend on the type of CIM modules implemented.

The task force will have to evaluate the informational sources that are available from the new CIM technology installation, from implementation management records, or from the financial reporting system already in place. The source of information on the status of the implementations will be clearly defined, and the project leader will be required to keep project management records depicting the achievement of module implementation milestones. The financial cost/benefit accrual can be obtained from the existing financial reporting system. Alternatively, the system in place for compliance reporting may require revision to reflect actual operating costs as portrayed by the "To Be" operational cost model. In addition, the indicators of improvement in the functional operations must also be identified.

To determine the source of positive impact or general progress information, each CIM module implementation should be examined with respect to the intangible benefits that were identified earlier in the CIM module evaluation. A CAD/CAM system implementation, for example, will impart improvements such as reduced time in design and redesign processes, greater accuracy of drawings, automatic dimension checking, and prove-out capability.

The task force must identify such indicators of improved design and manufacturing effectiveness as reduced lead time, reduced number of redesigns, reduced number of manufacturing processes, or more durable products in the case of the CAD/CAM implementation. The types of sources to be identified by the task force will vary according to the CIM module under consideration. (Conkol, 1985) These indicators of schedule adherence, cost/benefit accrual, and improvement impact will lead to the development of documented tracking mechanisms for each CIM module.

Establishing Tracking Procedures. With the sources of tracking information established, the task force can define formal procedures for implementation tracking and reporting to be carried out by the project leaders. The task force will work with the project leaders to develop reports and charts for tracking the status of the module implementations. The task force will also require a summarization reporting scheme for conveying the status of progress on the master CIM plan. (Punmani, 1985)

The tracking mechanisms must provide verifiable, auditable information. This mandate suggests that a formal tracking system become part of the company's everyday operations. Often, existing cost-management systems must be redesigned to reflect the new cost/benefit relationships that evolve as the CIM program is implemented. The decision to restructure the cost-management system should depend on the perceived usefulness of the information within the management decision-making process and the cost of modifying the system. Any restructuring of the cost-management system should be evolutionary and integrated into the strategic CIM plan.

In addition, intangible benefits such as reduced lead times should be tracked on a ongoing basis.

Establishing Performance Measures To clarify the difference between tracking source information and performance measures, the task force should consider tracking information to be supplying the appropriate data for further analysis, whereas performance measures indicate the current level of accomplishment. The ratios which are developed for the purpose of designating benefit accrual will compare the implementation tracking figures to the standards that existed before the module implementation program. These ratios can then be compared to the project improvement impact to determine the performance of the implementation. Similarly, the ratio of time expended during each step of the module implementation as compared to the projected schedule for attaining the milestones will designate the task group's implementation performance. These types of ratios should then be incorporated in the reporting mechanisms that were developed in the previous step.

A hypothetical example of a data sheet from a benefit-tracking report is shown in Table 2, which presents productivity ratio and cost savings for a CAD/CAM implementation. The productivity ratio represents the ratio of past average hours per part needed for CAD/CAM related activities (done manually) as compared to tracked hours utilizing the CAD/CAM

Table 2: Sample Benefit-Tracking Data Sheet

FOR THE MONTH OF MAY 1987

Category	Manual hrs. (std.)	CAD/CAM hrs. (actual)	Ratio	Savings
DESIGN	4.5	3.0	1.5	$45
DETAILING	6.0	6.0	1.0	0
ANALYSIS	6.0	1.5	4.0	$105
NC PROGRAMMING	3.0	1.5	2.0	$45
NC PROOFING	3.0	1.	2.0	$45
TOTALS	22.5	13.5	1.67	$240

AVERAGE PRODUCTIVITY RATIO = 1.67
SPECIFIC PRODUCTIVITY ($ saved/hours operated) = 17.78
COST OF SYSTEM = $13.50/hr.

system. The savings figure represents the savings per part in dollars resulting from reduced manhours, assuming a rate of $30 an hour.

In this example, the format of reporting data is demonstrated. The productivity ratio and average dollar savings per part are designated for labor hours only. In addition to this data sheet, a description of positive impacts on the related functions should accompany the report.

Ratios are characteristically used to indicate the health of a business. Performance ratios are therefore capable of representing results in terms familiar to senior executives. Such ratios as the productivity ratio indicate quite clearly how a functional area has improved in performance. Management may be expected to give solid support to the continuation of the CIM program if performance measures such as the productivity ratio and the financial benefit to cost ratio portray a positive impact on the business.

The task force and the project leaders will be responsible for developing performance measures that are cross departmental and reflect the new CIM benefits. (Zimmers, 1986)

Monitoring Performance

During this phase the task force will establish a plan for monitoring the master plan on an overall performance level. This plan will utilize performance measures developed for modules and the action plan and continually plot their course with charting techniques. In this manner it will be possible to identify trends and implementation problems--in some cases before they become detrimental. Most important, this plan must monitor the performance of the master plan in terms of its positive effect on the critical success factors of the business.

The plan for monitoring performance of the master plan must establish a series of summarized reporting procedures so that a concise account of the CIM program progress can be assembled for the CIM steering committee. This monitoring plan should set up periodic evaluations of the performance of the program as compared to the expected program performance throughout the implementation cycle. (Sun, 1985)

During the progress evaluation meetings, the task force should identify performance discrepancies between the projected and actual program implementation. Such measures as schedule adherence, benefit accrual, and positive impact actualization will be monitored and evaluated. The returns from these efforts of integration must be quantified so that they can be presented to the company executives to secure their continued support.

Developing Mechanisms for Implementation Control

The master plan must be both flexible and effective. By incorporating control mechanisms, the plan will have a higher probability of success. The implementation trends will be identified by the task force during the performance monitoring meetings. The task force will then be able to enact control measures to keep the implementation process going smoothly. They must identify areas that are not meeting their projected conditions and develop a plan for correcting the situation. The task force will mainly be concerned with identifying implementation delays and less than expected benefit returns and determining their effect on the overall implementation process. Where necessary, additional resources should be allocated. In the cases where major assumptions prove to be inaccurate, the task force must convey this information to the CIM steering committee.

As part of this phase, the task force should plan to present progress toward the master plan to the CIM steering committee approximately every three months. (Productivity International, 1981)
In this way the steering committee will be aware of any problems and will be able to assist in major decisions, authorize the allocation of additional resources, or modify the major thrust of the program.

The procedural mechanisms for monitoring performance should now be in place. An important feature for the company management to keep in mind is that this type of performance monitoring should continue well beyond the completion of the CIM implementation cycle. The monitoring activities will allow identification of new opportunities for application of CIM technologies and improvement of the business operations. There should, in addition, be beneficial side effects resulting from the continuation of performance monitoring. One benefit will likely be that company employees will strive to improve their operations in light of the strategic business objectives rather than the usual limited performance measures. These new performance measures, with management support, may evolve into standard reporting mechanisms to the benefit of the company.

Presenting the Master Plan to Senior Management

The presentation of the master plan should proceed similarly to the presentation of the conceptual design. The CIM task force and steering committee should utilize previously presented key graphical representations of the CIM program and newly developed charts and timetables to illustrate the characteristics of the plan. Any suggestions that were made by senior management during the presentation of the conceptual design will be addressed during this presentation.

The key aspects of the master plan to be presented include the integration policy, the newly formulated CIM modules, the time-phased cost/benefit accrual, the action plan, and the monitoring procedures. The main thrust of the master plan will be the aspects pertaining to project management and timing. Therefore, the steering committee should present a clearly charted course of action reflecting time schedules as well as manpower and resource requirements. During this presentation, the CIM program will become less overwhelming to the company executives because each step of the implementation will have an accompanying plan of action. (Punwani, 1985)

The company executives must also be convinced that the master plan is composed of a highly focused, carefully contemplated action plan that must, nevertheless, remain flexible. It must allow for changes in direction at future points during the program implementation. The performance monitoring procedures developed as part of the plan will provide control mechanisms for flexibly altering the CIM program to accommodate changes.

Once the presentation has been completed, the company executives and major shareholders should be given some time to examine and discuss it. Barring any unforeseen difficulties, the CIM task force and steering committee should expect to obtain final approval.

On the basis of management's willingness to commit annual capital funds to the CIM business strategy, the master plan can be finalized. (Punwani, 1985) The implementation cycle should be initiated upon the attainment of start-up investment funds and depending on the availability of other resources.

CASE STUDIES AND RESULTS

A comprehensive CIM planning methodology has now been presented. Case examples of actual applications of the CIM planning methodology will now be described. The validity of the proposed CIM planning methodology was tested by applying it under actual industrial conditions at three manufacturing facilities. These cases illustrate the capacity of the methodology to be flexibly modified to meet the needs of three diverse manufacturing enterprises.

LIMITATIONS OF THE CASE EXAMPLES

The CIM planning methodology described in this thesis was developed as a comprehensive approach for strategically planning CIM in contemporary manufacturing-oriented companies. The methodology consists of a step-by-step procedure for devising a CIM strategy for integrating all aspects of the company according to the business strategy. However, these case examples demonstrate that it is not necessary to utilize the entire methodology in order to obtain benefits from CIM planning.

Limitations Pertaining to Individual Situations

The companies presented in these case studies are presently in various stages of their CIM programs. In addition, their particular circumstances do not warrant application of the full spectrum of CIM planning activities. Therefore, not all stages of the methodology were applied to each company. Nevertheless, these companies provide valuable tests of the CIM planning methodology as utilized in actual industrial conditions.

Limitations Pertaining to Confidentiality

The identity of the companies and several details pertaining to their situations have been omitted from this thesis because much of the information generated in a methodology of this type is confidential. Competing organizations might identify detailed information that could be used competitively against these firms. Therefore, as requested by these companies, their identity and corporate details will remain unspecified. In addition, many of the organizational models developed during these cases have been altered at the request of management.

GENERAL DESCRIPTION

The three case examples will be referred to as Company A, Company B, and Company C. All three companies are located in Pennsylvania. The background of these companies is as follows.

Company A

Company A is a metals fabrication company that restructured its operations to public ownership in the early 1980s. It company-wide employment level has been considerably reduced. Previously, the facility had large middle-management ranks and a substantial labor force. As Company A began its restructuring period, it reduced the middle management ranks and also reduced its labor force to a lesser degree. The main employee base has therefore become primarily direct ("blue-collar") laborers. The company currently employes approximately 700 persons.

Company A's production operation is akin to process industries in many ways, since the product is handled in several forms throughout the production process. As a result, the production flow is relatively the same for most products. Company A's products are made to industry standards and to customized design.

Company B

This company manufactures processing equipment for a specialized industry. It produces parts in small to medium batch sizes (from 1 to 100 parts). The facility is actually a large machine shop operation of a medium-sized company. The parts it manufactures are those that require a large percentage of metal-machining operations. These parts are utilized in new processing equipment or sold as replacement parts for equipment in service. Company B machines, inspects, assembles, and tests its products at this location. Similarly to Company A's, the workforce is principally composed of direct laborers. Many of the machining operations are manual-labor intense. Approximately 150 persons are employed at this plant.

Company C

Company C is a manufacturer of fine furniture. It is actually a division of a foreign-owned parent company. The operations of this division were started up in 1984 in an attempt to broaden the product line of the parent company. The actual manufacturing of the fine wood furniture products did not start until one year later. The fabrication operations were brought in-house to give the company more control over its lead times and to reduce the level of required inventories. As a result of bringing the fabrication operations in-house the facility is able to manufacture products in lots of 50 to 100 instead of purchasing lot sizes of 500 or more.

Company C designs, fabricates, assembles, and finishes fine wood furniture. All hardware and related items are purchased and assembled with the wood subassembly. There is a substantial amount of design activity, although only a few of the designs are accepted as new models each year. Therefore, the product line is well defined and limited in size (approximately 40 items). Since many of the items are purchased and the wood fabrication operation is fairly new, the direct labor force is not so substantial a percentage of the work force as is the case with the other two companies. Company C employs approximately 50 persons.

Lehigh University CIM Lab Participation

The CIM Lab is one of several research labs operating at Lehigh University in Bethlehem, Pennsylvania. This Computer Integrated Manufacturing Laboratory serves as both a research and consulting centerfor industrial applications of computer technology and as an educational facility for industrial seminar participants and Lehigh University students. The equipment located at the CIM Lab provides the facilities for practical computer applications research for manufcturing-oriented industries.

At each of the case companies, the management in some manner had become aware of computer-integrated manufacturing techniques and had pursued the assistance of the Lehigh University's CIM Laboratory to access the application of CIM at their companies. Each company had different reasons for pursuing this direction.

Company A, for example, wished to remain lean in management and to keep its costs of operation down by utilizing CIM technologies to assist in its design, data collection, and reporting activities. In addition, Company A had a strong need to assess the replacement of its existing CAM system as a precaution against equipment failure and to provide added competitive advantage. Company B looked to CIM technology to assist in reducing manual labor content, adding flexibility of manufacturing, and reducing required inventory levels. Company C pursued a CIM direction to reduce manufacturing costs through better design and to enhance the creation of production control documentation.

During discussions between the Lehigh University CIM Lab and management, it was established that the CIM Lab would assist each of these companies in conducting a CIM planning program. This decision was based on the assumption that business firms should examine CIM applications strategically throughout their entire business operations before choosing specific technologies for implementation.

Each case will now be presented to demonstrate the activities that were conducted at these facilities.

COMPANY A

Senior management of Company A solicited the assistance of the Lehigh University CIM Lab in assessing the application of CIM technologies in their business. As a result of discussions with these managers it was decided that five of the six stages of the CIM planning methodology would best address management's stated objectives: program initiation, program organization, "As Is" analysis, needs analysis, and conceptual design.

These stages were performed with various degrees of intensity. For example, the "As Is" analysis was addressed very thoroughly while the two preceding stages (program initiation and program organization) were only partially addressed. This variation was due to the situation of the company, and the planning approach reflected management preference.

Program Initiation

The program initiation activities were somewhat limited in scope because senior management showed strong initial interest in the utilization of CIM concepts at their company. One of the main goals of the program initiation stage is to gain the support of upper management. This stage would normally be important if lower-level managers or technical professionals were initiating the CIM investigation. In addition, senior management were interested in assessing particular technologies within a relatively short turnaround time. These circumstances resulted in limiting the program initiation activities to presenting CIM concepts and basically educating top management in the area of integration and its benefits.

Program Organization

During the program organization stage senior management again showed strong interest in CIM by agreeing to act as the CIM steering committee. The role of CIM champion or the individual given the responsibility for monitoring and controlling the CIM planning activities was assinged to the vice president of manufacturing.

A project team for performing the CIM planning activities was then established. It consisted of one technical professional from Company A and a team of four individuals from the Lehigh CIM Lab. In addition, employees were to be assigned responsibilities for participation in the planning activities as their functional areas became involved.

The next activity was to establish the initial strategic business goals of the company. Eventually, it was established that Company A was most interested in maintaining a high standard of quality while reducing manufacturing costs and improving customer service levels. It should be noted that there was no objective discussion on this matter, and top management did not collectively authorize these goals.

"As Is" Analysis

The "As Is" analysis constituted the major concentration of activities. Company A's management, however, felt they did not need to develop a facility and equipment profile. In addition, they felt their product flow was fairly straightforward and opted not to participate in a product flow analysis.

Company A's functional hierarchy was investigated to establish major organizational groupings. This activity was initially approached in conjunction with the information flow analysis. Early activities in analyzing information flow had resulted in a functional breakdown of the informational flow through the company. In addition, the company had an organizational chart which signified the reporting hierarchy in the company. Utilizing this chart, the functional flow diagram, and personnel department records that listed individual job responsibilities, the task group was able to develop a functional hierarchy of the company. (See Figure 23a and b.)

Figure 23.a Information Flow for Design

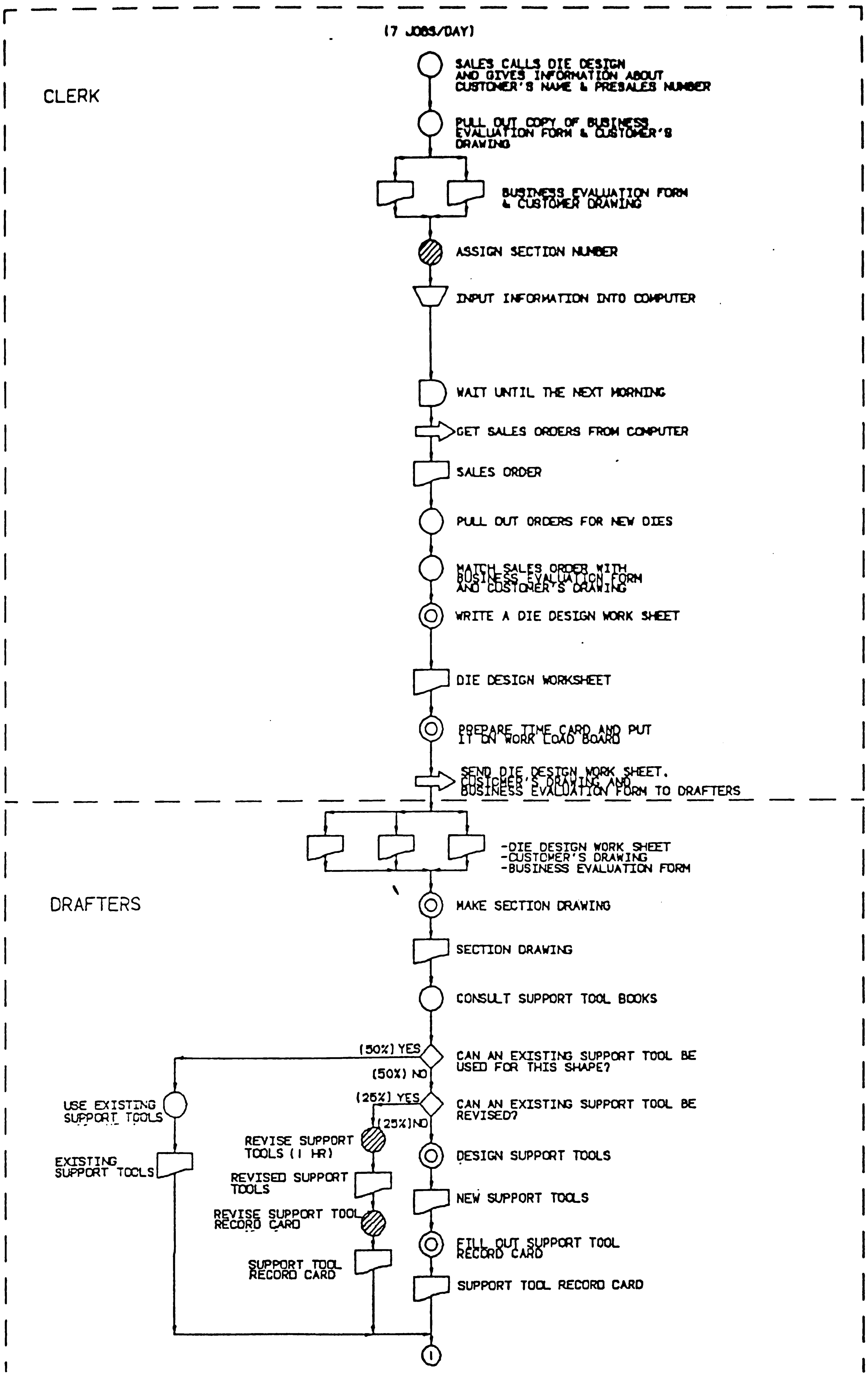
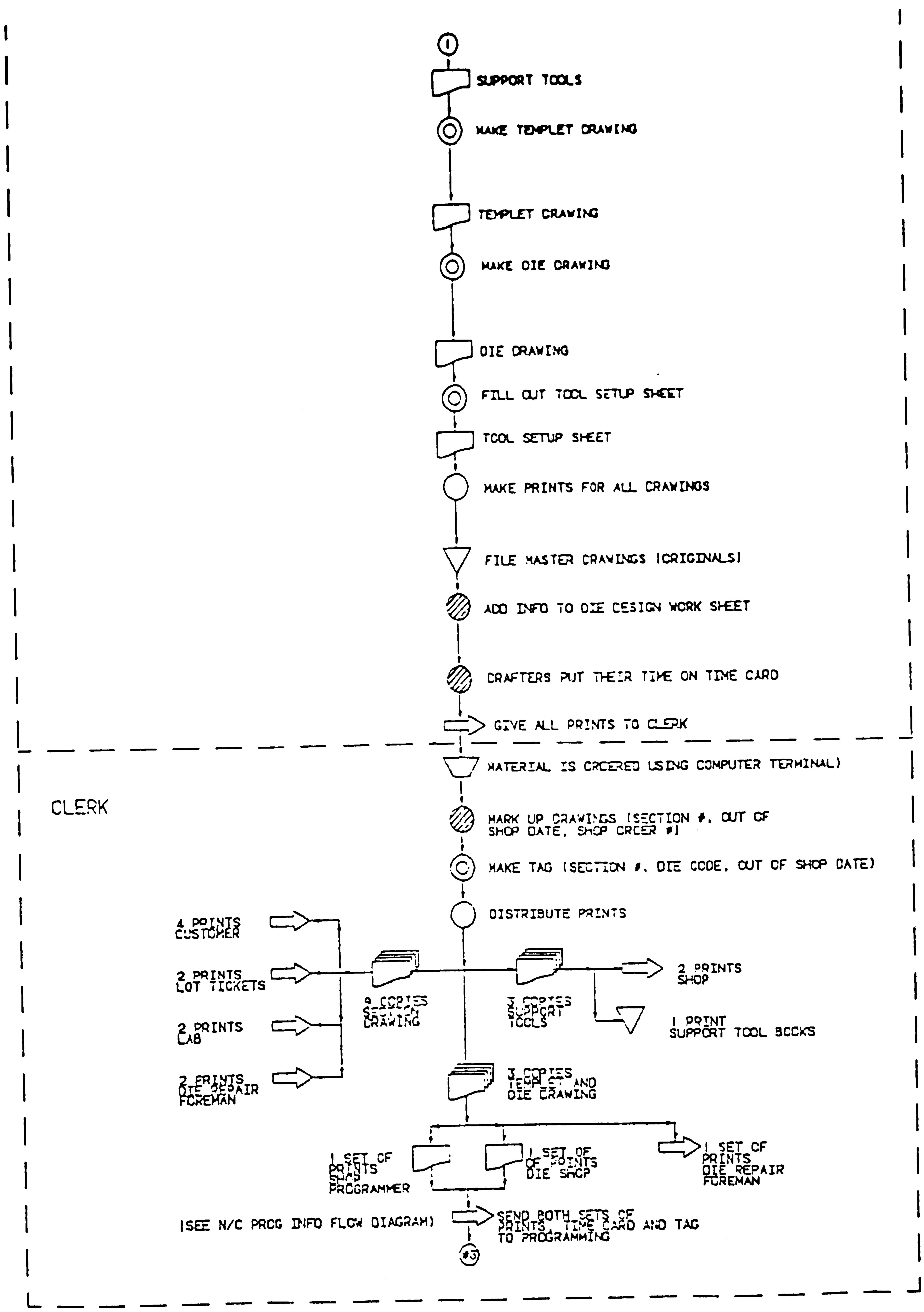


Figure 23.b Information Flow for Design



The informational flow analysis began with the functional level flow diagram. Once this was completed, the task group had a guide for completing the detailed modeling activities of the information flow analysis. The final product of this analysis was an information flow diagram that will provide a detailed model of the information flow through specific areas of the company.

The procedure followed for constructing the information flow diagram was first to identify the individuals who performed the information handling activities in each functional area of the company. The functional level diagram identified target areas for investigation. The order in which the information flow was documented proved to be logical. The flow was tracked from initial sales-order generation through the shipping operation. Management had stressed the importance of concentrating on the design-related tasks. Therefore, that particular area was investigated more thoroughly than the others.

The CIM technology that was to be investigated for application and extent of integration was CAD/CAM. Company A currently utilized an obsolescent computer-aided manufacturing (CAM) system to assist in tooling production. Design and analysis activities were performed manually at the outset of the CIM planning activities, since the design and manufacture of tooling was so vital to lead-time reduction and high quality objectives. A sample operational cost model is shown in Figure 24a and b.

These diagrams present average cost per part in units of time. The financial costs were then calculated internally to determine the amount of labor cost incurred throughout the activities involving design and machine tool path generation. These data were later used in the justification process.

Company A management then decided to concentrate exclusively on the CAD/CAM application before going on with the CIM planning activities. The needs analysis stage consequently concentrated on the design and fabrication of processing tooling for production.

Figure 24.a Sample Operational Cost Model

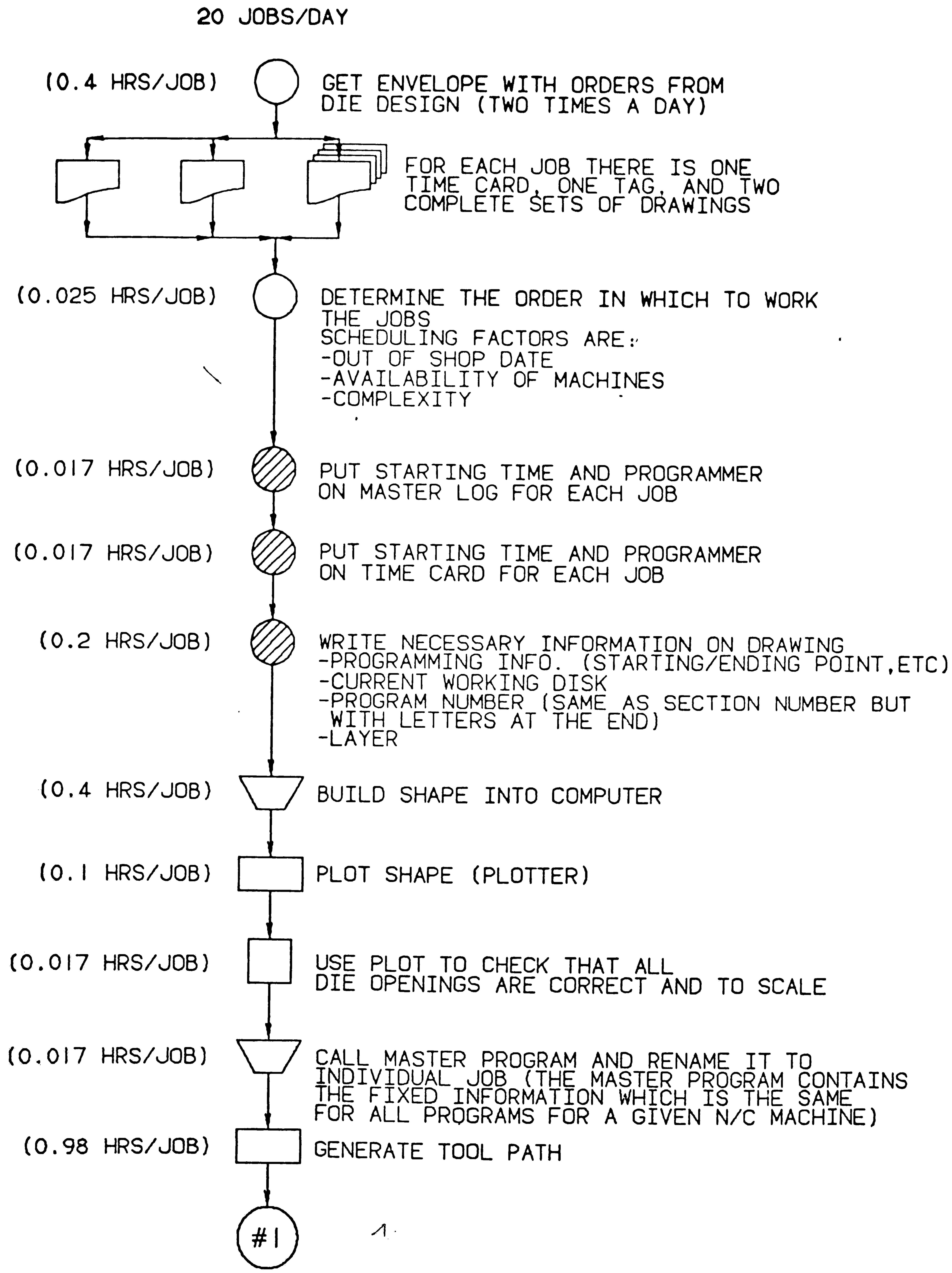
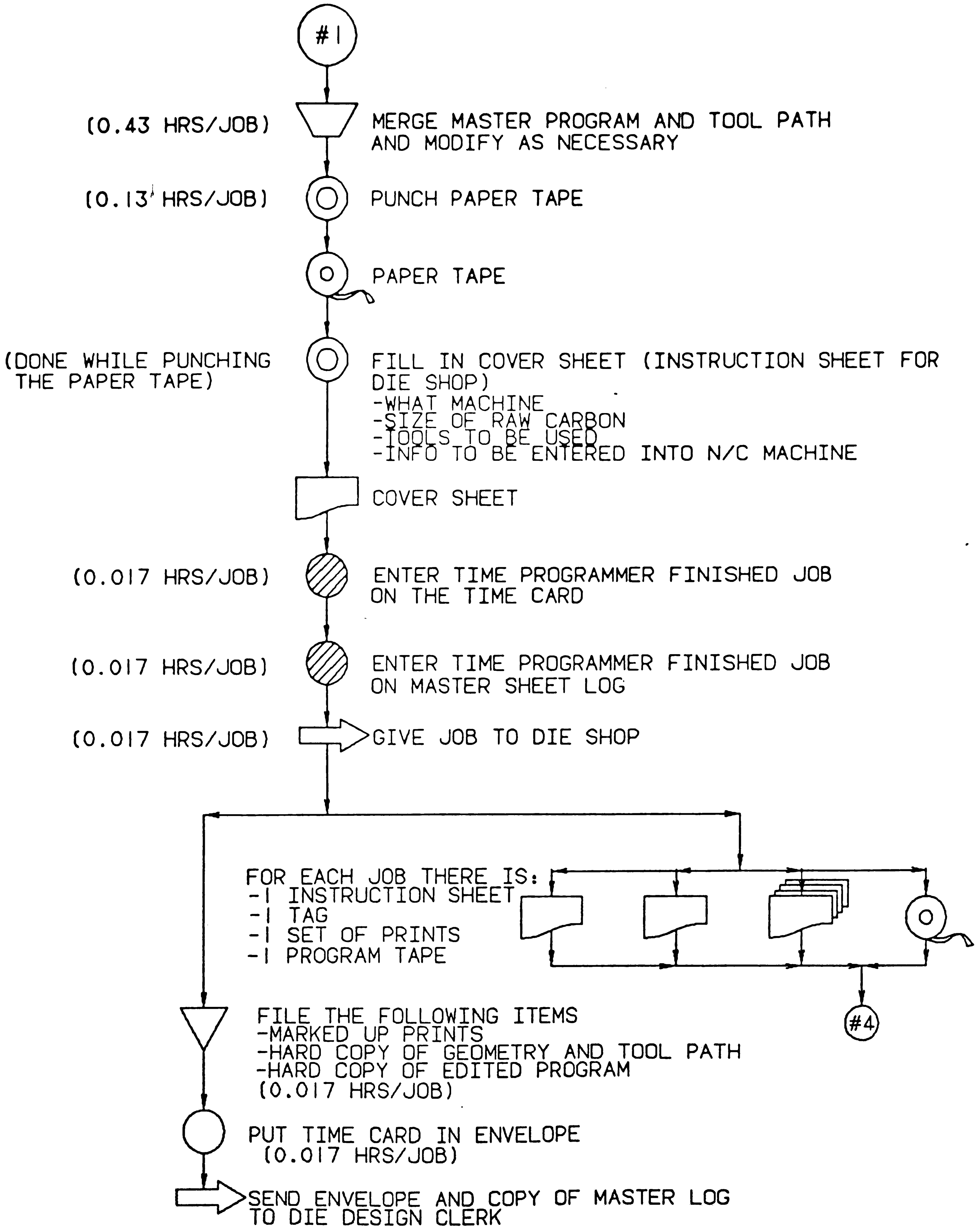


Figure 24.b Sample Operational Cost Model (Continued)



Needs Analysis

During this stage the company formed a multi-disciplinary task force consisting of individuals from sales, marketing, accounting, industrial engineering, manufacturing management, design, a tooling shop supervisor, a laborer from the tooling shop, and Lehigh CIM Lab staff. The meetings were chaired by the vice president of manufacturing. Major strategic issues were to be discussed in relation to upgrading the design and manufacturing operations.

One of the first issues was to establish whether the company ought to produce its own tooling or subcontract tooling production out. In-house production costs were then compared to quoted vendor prices and were found to be similar. It was also determined that the company might become dependent on their outside sources of tooling and subsequently would not have the flexibility to respond rapidly to emergency production conditions. Therefore, it was decided to keep tooling production in-house and to integrate those operations to manufacture tooling for their product line more efficiently and effectively.

Having identified the directives to reduce lead times, improve quality, and reduce costs associated with tooling production, the task force next examined specific design and manufacturing needs. Representatives from marketing projected profitable product lines to be focused on during the needs analysis. All areas that would be affected by the CAD/CAM application were examined for improvement potential and the requirements with which the system would have to comply. Included among the other requirements was the capability to develop an expert design system with the CAD/CAM technology.

The industrial engineer was then assigned the task of determining projections of estimated functional improvements that would result from the CAD/CAM implementation. These estimates were developed by utilizing published improvement projections from industry surveys and data documented on the operations model and applying conservative estimates of the improvement potential that might be actualized by Company A. The projected improvement potential was substantial, and Company A consequently continued with the application development.

To complete the needs analysis activities with respect to the CAD/CAM system selection, Company A, with the assistance of the CIM Lab, conducted a CAD/CAM system selection activity. The functional requirements that had been established earlier were weighted to reflect their relative importance to the company. Several systems were then analyzed to determine which CAD/CAM system best matched the company's needs. Each CAD/CAM system was rated on each criterion. By multiplying that rating by the criterion weight and adding the results for a particular system, the system that best met the company's requirements was identified.

Management took other criteria such as price into consideration and then selected a specific CAD/CAM system.

Conceptual Design

To determine the extent of integration that should be provided between the CAD/CAM system and existing computer systems, a conceptual design of the configuration was prepared for upper management. The company then purchased the system that had been identified and began implementation.

COMPANY B

The application of the CIM planning activities at Company B was chosen as a typical case example. As with Company A, interest in investigation CIM activities was initiated by company management. Like Company A's, Company B's senior and plant managers were not interested in a complete company-wide CIM program. Instead, they wanted to explore the potential manufacturing-oriented benefits they might experience through utilization of CIM technologies at their machine shop operation.

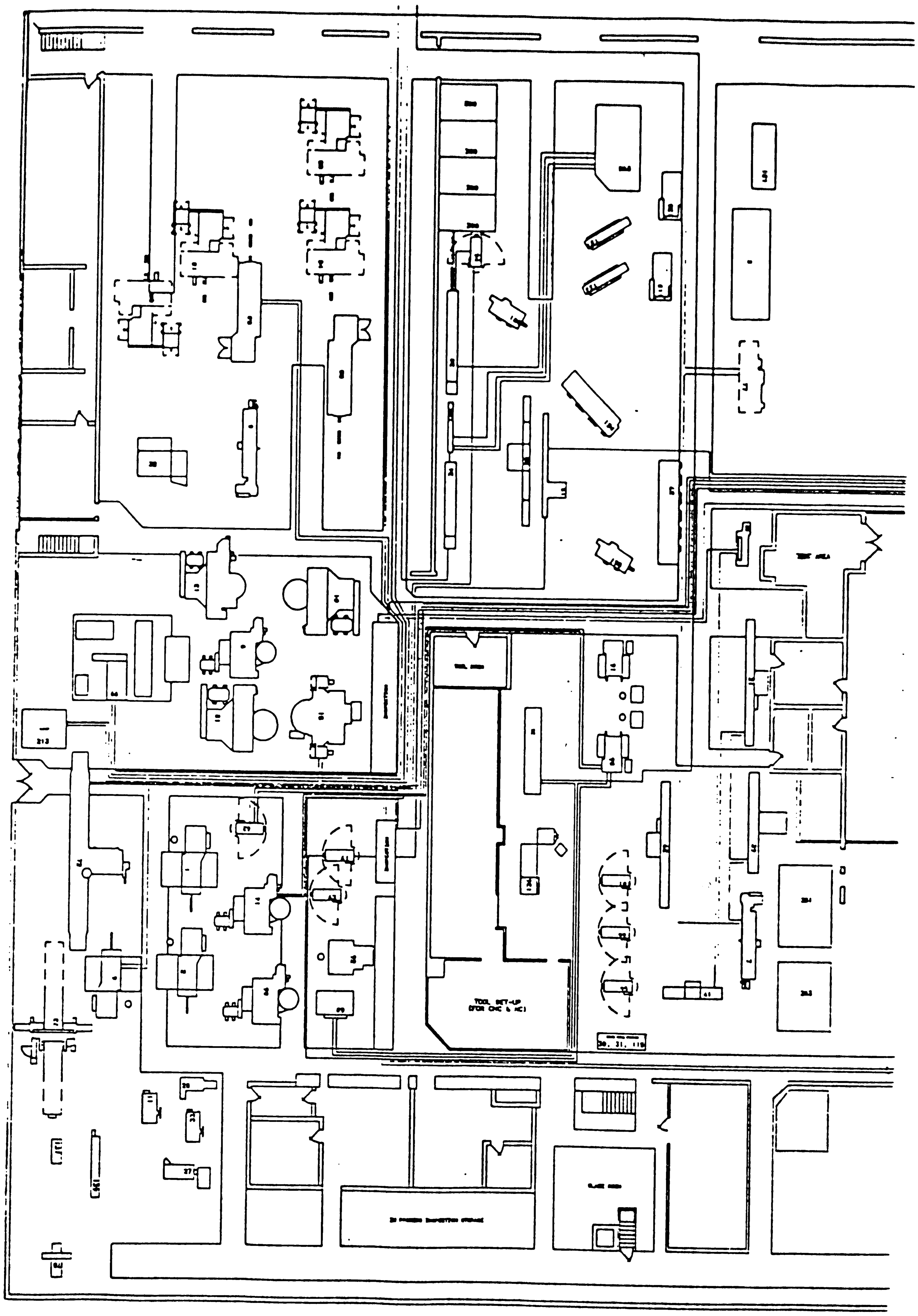
This company was chosen as a case study of the application of the CIM planning methodology because it provided an example of a discrete parts manufacturing/ machine shop operation. Therefore, Company B demonstrates certain aspects of the CIM planning methodology unlike to the previous case.

Company B solicited the Lehigh University's CIM Lab to perform a study of its plant equipment and product line and to determine a means to attain a more effective manufacturing operation through the utilization of CIM technologies. The CIM Lab in conjunction with the management staff at the machine shop facility developed an approach to this project that utilized steps from the "As Is" and needs analysis stages. The overall objective was to apply group technology concepts to Company B's plant facilities and product flow to prepare a basis for adopting computer-aided manufacturing (CAM) technologies.

"As Is" Analysis

The "As Is" analysis consisted of performing a facility and equipment profile and product flow analysis for this situation. The activities performed for the development of the facility and equipment profile included modeling the complete manufacturing facilities layout on a computer graphics system (Figure 25). This step will allow for the flexible development of several alternative layouts and will later serve as a basis for product flow analysis. Since the focus of the CIM planning effort was on manufacturing efficiency, plant and equipment modeling was the only activity performed as part of the facility profile step.

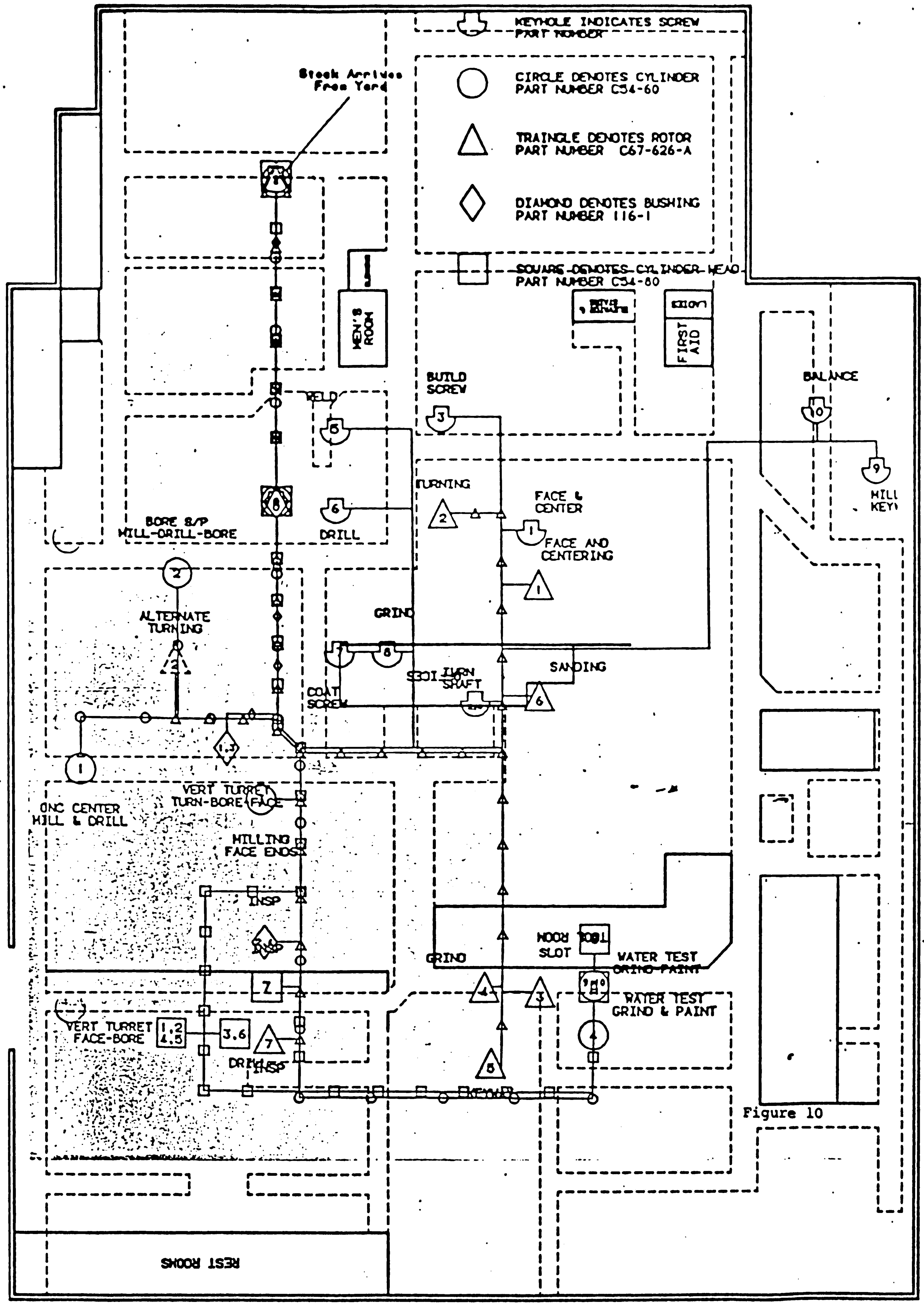
Figure 25: Facilities Layout for Company B



Product flow analysis, in contrast, received the heaviest concentration of effort. The first area of activity was to examine the type of production the facility was engaged in. Over 3000 parts were identified as having been produced in the last year. It was estimated that the highest percentage of production time was consumed by a much smaller set of parts which could be grouped into families. Company B's management then decided to continue with the investigation into applying group technology concepts to their manufacturing operation.

The next step was to have the process planners differentiate high-volume parts. Once this had been done, the flow of these parts was modeled on the facilities layout (Figure 26).

Figure 26: High-Volume-Part Product Flow



As demonstrated by Figure 26, the product flows contained major inefficiencies owing to a random placement of equipment that had evolved years earlier from a process layout.

It was then decided to engage in a thorough product analysis activity to identify groupings of parts. Statistical analysis was used to determine the high-priority parts on the basis of total machining time recorded over the preceding year. High-priority parts were defined as those representing the upper 30 percent of the recorded machining time, and 58 parts of the 3229 produced were thereby designated as high priority.

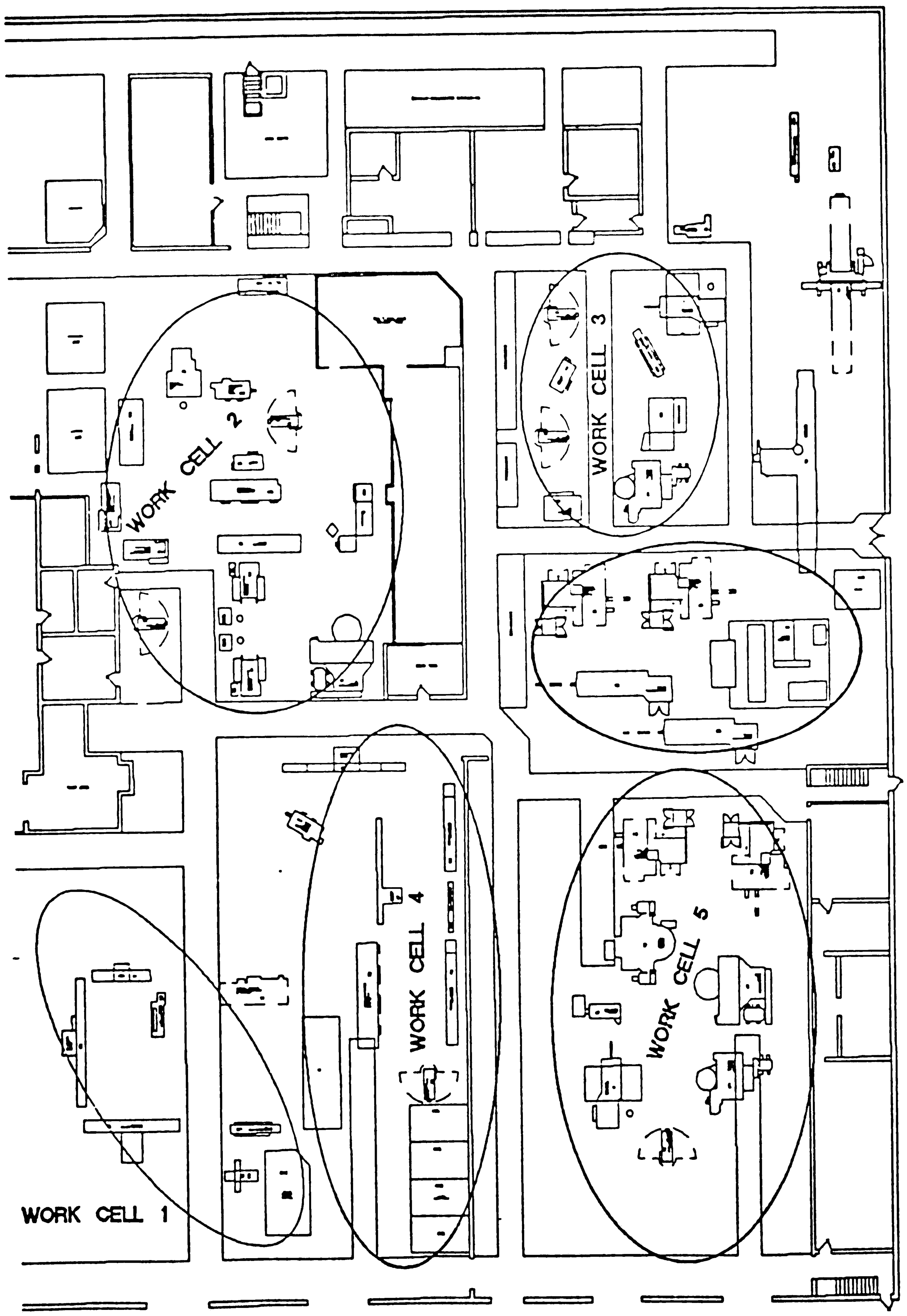
The product analysis was made possible by the fact that Company B kept computer records on all production activities. The statistical analysis was accomplished by downloading the IBM mainframe file of production records to a personal computer and loading the large file into dBase III software (dBase III is a relational database system that allows searching, sorting, selecting, and displaying of records in the database). dBase III allowed CIM Lab personnel to sort the file entities by production hours.

Once the high-priority parts had been established, the machine tools utilized to produce those parts were identified by a process referred to as production flow analysis. The machine tools that were commonly utilized to produce sets of similar parts were grouped into hypothetical cells. The parts common to these cells made up part families. In this manner it was possible to establish six part families. This process was basically repeated until 75 percent of machining time was accounted for. It was found that 520 parts accounted for 75 percent of the machining time. After these parts were analyzed for part groupings, a seventh part family was added.

Needs Analysis

Once these parts had been grouped into families, a needs analysis was performed utilizing the data generated up to this point. The objective of the needs analysis was to establish the machining capabilities required for the production of each part family. Manufacturing cells were then designed with existing equipment (Figure 27).

Figure 27: Machine Cells for Company B



In some cases a particular machine was utilized by parts from different cells. In these cases, similar pieces of equipment were distributed to the different cells to provide the appropriate machining capability in each cell. This activity served to establish the machining capabilities required of each cell.

The final step in the needs analysis was to assess the application of new flexible CNC (computer numerical control) machine tools to replace multiple existing machines. This would reduce manual labor requirements, improve reproducibility, and reduce material handling.

COMPANY C

Company C serves as a test case for the application of the CIM planning methodology to a nonmetals fabrication operation. In this company's case the fabricated product material is wood. Company C also provides an example of medium-batch manufacturing in a relatively small company. The underlying situation in this case is similar to that of the other cases. Senior management of the division solicited the assistance of the Lehigh CIM Lab to assess applications of CIM-based technologies to their manufacturing operation.

The general manager of this division showed extreme interest in the application of CIM technology to this firm's operations. This individual had served as a catalyst for applying computer-aided design in this division and was now interested in identifying available alternatives for further integration of business operations through the application of CIM planning procedures. In addition, this individual was very active in the planning activities.

The stages of CIM planning which were partially applied to Company C's situation included the "As Is" analysis, needs analysis, and conceptual design.

"As Is" Analysis

The first activity undertaken was documentation of information flow through the company to identify areas for improvement. Management's goals were to improve design and production control information development in order to enhance the efficiency of the manufacturing operation. The "As Is" analysis activity produced information flow diagrams that modeled the channels of information flow through the division required for the manufacture of its product.

Needs Analysis

The next step consisted of a needs analysis to determine the information required for production and the current means of generating this information. Examination of the information flow diagram identified inefficiencies in part production information and in reporting and data collection procedures. In addition, a need was identified to apply group technology concepts to install part standardization and to structure a database of part information. Parts were first examined for similarities in manufacturing processes and shape. It was determined that group technology concepts could be utilized by this company to capitalize on the benefits of standard part production and part grouping.

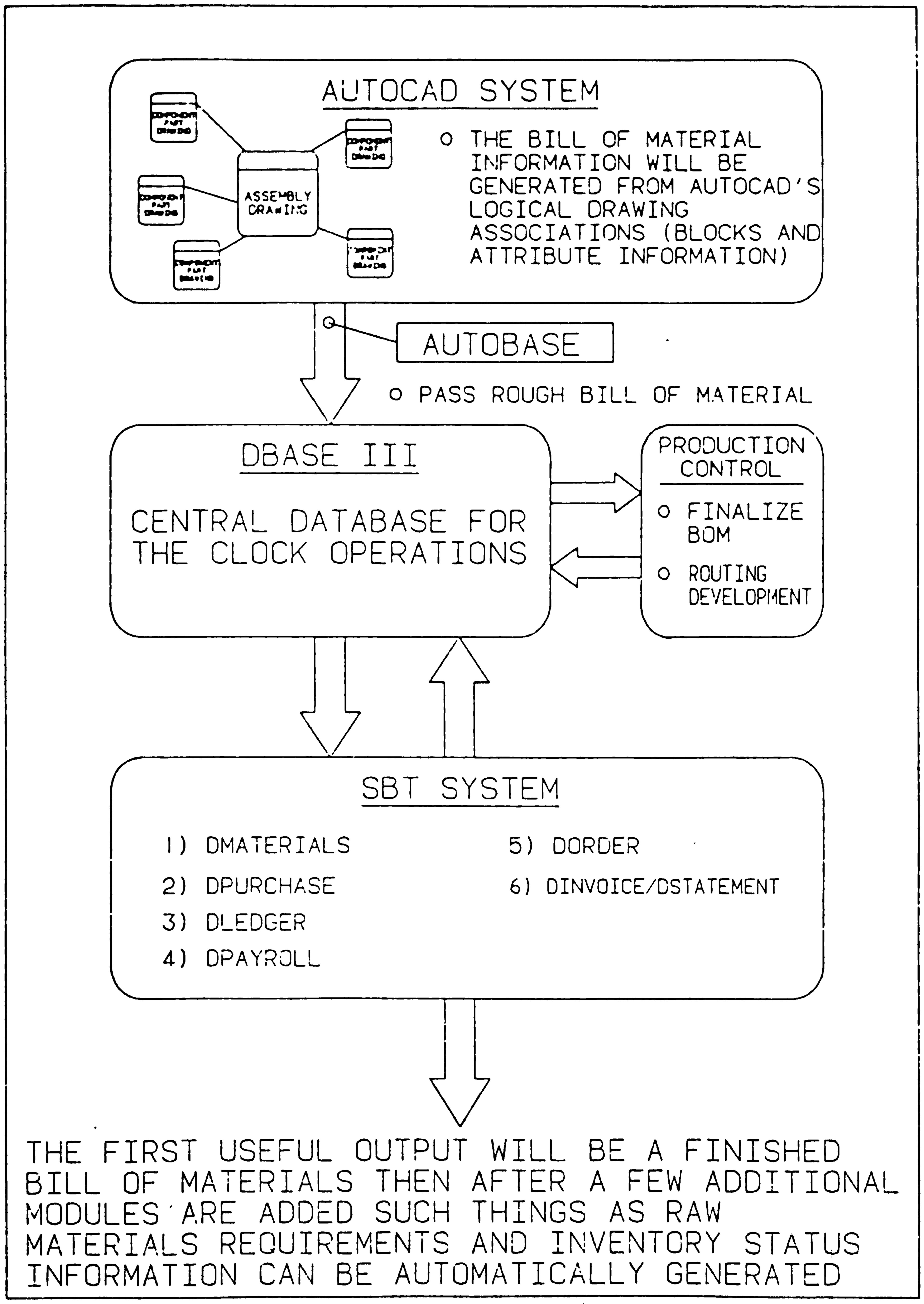
During this activity, the identification of market-related requirements was completed. The facility manufactures standard products, but customer-specified customized components are added to some of the products. This situation introduces the requirement of short lead times for the customization of the final product.

Conceptual Design

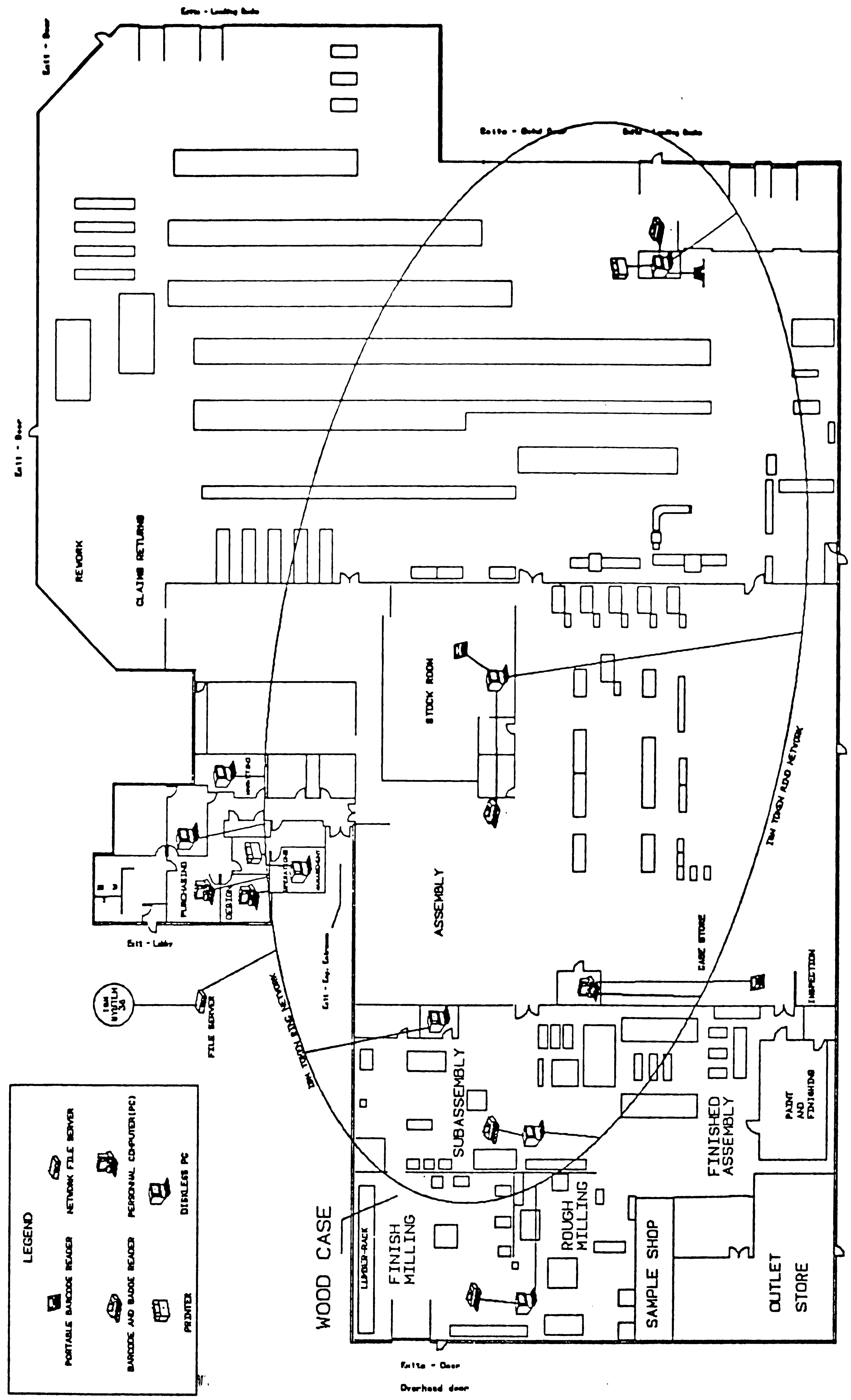
The conceptual design stage was then enacted. The first task was to develop a part-coding scheme to facilitate the structured generation and tracking of part-production information. A conceptual design of part-production information generation was then completed. This activity developed a plan for generating a bill of materials from the CAD system and interfacing that bill of material with a business software package to perform such functions as automatically generating bills of materials, track accounting information, and vendor lists (Figure 28).

The next step was the development of a data collection and reporting network for streamlining the monitoring and control of the production operation (Figure 29). This conceptual design was then presented to divisional and corporate management for review.

Figure 28 Conceptual Interface Between CAD System and Business System



Firgure 29: Conceptual Networking Schematic



RESULTS

The results obtained from the application of portions of the CIM planning methodology in the case situations described were generally successful in that company managers were provided with the assessment that they had requested. Management's subsequent use of those assessments did not in all cases conform to the expectations or intentions of the CIM plan.

Company A

In the case of Company A, the "As Is" analysis was intended to comprehensively analyze the company's manufacturing oriented information flow--a long, intensive process in a company of this size. The investigator believes that the absence of immediate, tangible results led management to lose interest and withdraw support from the planning process. The "As Is" analysis as conceived in the proposed methodology is intended only to lead to the next stage, the needs analysis. Tangible benefits cannot be realized until after the program implementation begins.

In this case, management often wanted to focus the analysis effort on preconceived problem areas and to limit the planning activities. Although this tendency is understandable, it does not allow the total strategic approach to CIM planning. Once the CAD/CAM system selection was completed, management canceled further CIM planning activities.

Company B

The case involving Company B was slightly different. In this case, utilization of CIM planning assistance from the Lehigh CIM Lab was mandated by senior management of the parent corporation. In addition, division plant management was not really part of a unified corporate-wide CIM planning program. Instead, they directed specific CIM planning investigations which were initiated to address specific preconceived problems. The CIM planning task force therefore made the best of the situation by applying portions of the planning procedures to Company B's situation. Their goal was to improve the company's manufacturing efficiency.

The plant management determined that the likelihood of improving the effectiveness of the manufacturing operation by implementing CIM technology was indeed viable. Although the project met management needs as presented, a detailed cost/benefit analysis should have been performed before making final decisions.

The benefits realized through the CIM planning activities that were performed at Company B included a part-grouping scheme and machine cell concept which will serve as a basis for additional CIM technology applications. One conclusion to be derived from this experience is that management's withdrawal of support may be attributed to insufficient focus on the program initiation stage.

Company C

The results obtained at Company C support the hypothesis that the methodology proposed in this thesis will in fact have far-reaching strategic impact. At this company the strong support of a member of upper management provided the backing for conducting a more comprehensive CIM planning activity than in the other case examples. By conducting an "As Is" analysis on the overall business operation, it was possible to conceptually design integrated business operations which permitted the interfacing of the various major business functions.

The conceptual design provided a plan for integrating manufacturing with design, purchasing, accounting, and shipping and, in addition, linking the division to the parent company via an information systems link. Financial concerns were not examined as part of this program, but the conceptual design has portrayed a possible direction for improving overall operational effectiveness.

As a result of these CIM planning activities the parent corporation has expressed interest in implementing a CIM planning program.

General Conclusions

In general, the investigator observed that a major barrier to implementing CIM programs and devoting time and resources for planning activities is the delayed accrual of tangible benefits. This characteristic led the management of the case companies to become dissatisfied with the strategic CIM planning effort and thereby tended to limit the scope of planning activities. Planning efforts were then focused on the areas management had previously assumed to be the source of inefficiency.

Investment resources in most companies are scarce, and many projects generally were competing for the available funds. Therefore, upper management will need to weigh strategic in addition to financial implications in order to justify CIM planning and implementation projects. In the case of company A and Company B, it is conjectured that more emphasis should have been placed on program initiation activities. It is probable that management did not initially comprehend the magnitude of the CIM planning task.

Specifically, the education of both senior and middle-level management should have stressed the concepts underlying strategic business planning. Education sessions provided on a periodic basis might have given corporate management a better understanding of the strategic impact of integration on the business operations. In addition, these sessions might have strengthened the commitment of the senior managers to the CIM planning activity.

As a final observation of the case study results, it was demonstrated that the CIM planning methodology is capable of being flexibly modified in response to the specific circumstances of a manufacturing-oriented enterprise while still providing the benefits attributed to it.

SUMMARY

The problem addresses in this thesis is the apparent reluctance of U.S. manufacturing-oriented companies to prepare appropriately for the implementation of computer-integrated manufacturing (CIM). A methodology for addressing the problem is proposed, and case examples of the methodology in use in three manufacturing facilities is presented.

METHODOLOGY

The author has developed a CIM planning methodology that enables manufacturing-oriented businesses to assess opportunities for utilization of CIM technologies and to develop an integrated strategy for successful implementation of CIM. The proposed CIM planning cycle consists of six principal stages: (1) program initiation, (2) program organization, (3) "As Is" analysis, (4) needs analysis, (5) conceptual design, and (6) master plan.

Program Initiation

The objective of this stage is to obtain the full support of senior management for a company-wide CIM planning effort. Such support is perceived as critical to successful implementation of CIM. Senior management is first presented with the benefits of CIM. Once interest is aroused, senior management is educated regarding the importance of planning, the concept of integration, the methodology for CIM planning, the role of senior management in the planning effort, the importance of education and training at all levels, and the approach to be used in investment justification.

Program Organization

Four critical areas of program organization are addressed: (1) the establishment of an organizational structure for CIM planning consisting of a CIM steering committee and a CIM task force; (2) the formulation by senior management of preliminary strategic marketing goals; (3) the planning of a company-wide education and training program beginning with the education of the task force leaders; and (4) the establishment of project management guidelines addressing consensus decision making, leadership roles, and project control issues.

"As Is" Analysis

In order to undertake a CIM project, senior management and the CIM task force must first obtain a thorough understanding of the existing company infrastructure and its mode of operation. The methodology presented utilizes detailed collection of data together with modeling techniques to facilitate conceptualization of business operations. Graphical facility representations, product flow models, an information flow model, an operational cost model, and additional documentation techniques enable CIM task force members first to comprehend the company infrastructure, then to present their findings to senior management, and finally to use those findings for planning purposes.

Needs Analysis

A market analysis is utilized to enable senior management to refine the preliminary strategic goals formulated in the program initiation stage into a five- to fifteen-year grand strategy and to identify the factors critical to the success of the business (CSFs). The hierarchical values determined for the CSFs are utilized in a systematic breakdown and prioritization of business functions from the highest level to the lowest. Requirements for functional improvements are similarly identified and prioritized. The application of CIM technologies to the identified requirements is then assessed and the functional improvement potential of these technologies is determined.

Conceptual Design

The data generated in earlier stages of the CIM planning cycle is utilized to formulate a "To Be" conceptual design of company operations according to the priorities previously established. Functional requirements are matched with available technologies and procedural changes in progressive steps consisting of (1) developing alternative CIM scenarios, (2) establishing a single best scenario, and (3) analyzing each component of that scenario to determine the optimal scope of improvement and thereby to derive the conceptual design for integration of the business operations. A generalized set of CIM specifications can then be developed by the CIM task force and the conceptual design presented to senior management for review and approval.

Master Plan

The master plan developed in the final stage of CIM planning consists of (1) a CIM module evaluation to provide a final assessment of the value of CIM applications, (2) a strategy for integration of the applications in terms of strategic goals and existing operations, (3) a time-phased an action plan incorporating the required steps for implementation of each module and a schedule for completion, and (4) procedural mechanisms for monitoring performance. Presentation of the master plan to senior management for review and establishment of the implementation program by management complete the CIM planning cycle.

CASE STUDY RESULTS

A series of three case studies was undertaken to demonstrate the feasibility of the proposed CIM planning methodology. Utilization of the proposed methodology resulted in the completion of comprehensive CIM implementation plans at all three demonstration sites. However, full implementation was successfully achieved at only one of the three sites. The results obtained at the other two sites confirmed the hypothesis that establishing and maintaining the support of senior management is crucial to successful CIM implementation.

In these two cases, senior management's initial enthusiasm regarding CIM technology and the CIM planning process diminished in the absence of fast, tangible results. Planning activities were consequently curtailed. Nevertheless, utilization of portions of the proposed methodology provided sufficient strategic planning to enable management to adopt a broader business perspective when evaluating the CIM technologies actually implemented and to achieve cumulative benefits throughout their operations.

In all three cases, utilization of the proposed methodology enabled senior management to assess the strategic impact of new CIM technologies. Therefore, it is concluded that the case studies substantiated the validity of the CIM planning methodology presented in this paper.

CONCLUSION

The investigator concludes that when the CIM planning methodology presented in this thesis is applied at manufacturing-oriented business enterprises, it will provide a workable implementation plan for CIM technologies. This conclusion is supported by the documented results of three case studies in which the methodology was applied at variously sized industrial concerns.

The methodology was developed to address common problems identified by research as being associated with the approach of manufacturing-oriented enterprises to the planning of CIM implementation. For example, applied research had determined that, in many cases, insufficient planning and a lack of management commitment contribute to ineffective implementation of CIM technologies.

The proposed methodology addresses CIM planning in a "top-down," hierarchical manner from the perspective of the ultimate strategic goals and objectives of each of the ultimate strategic goals and objectives of each individual enterprise. It facilitates the systematic functional breakdown of company operations and subsequent analysis of the needs of each subcomponent of the enterprise in relation to the factors determined to be crucial to its success. The procedures are designed to enable senior management to maximize the strategic benefits of CIM technologies, to ensure efficient investment of resources, and to provide cumulative benefits throughout the enterprise.

The application of the proposed CIM planning methodology in test cases has demonstrated that the utilization of selected portions of the planning procedures will produce results superior to those currently being achieved with traditional methods. The case studies also demonstrate that full utilization of the methodology in a company-wide, comprehensive planning effort achieves greater strategic returns than incomplete utilization.

It has been proposed that comprehensive application of the full CIM planning cycle described in this thesis will lead to the creation of a master plan for networking technology, management, and functional personnel and will lay the foundation for adynamically responsive business operation. The investigator concludes that the proposed methodology has been proved by the case studies to be capable of achieving its stated objectives.

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